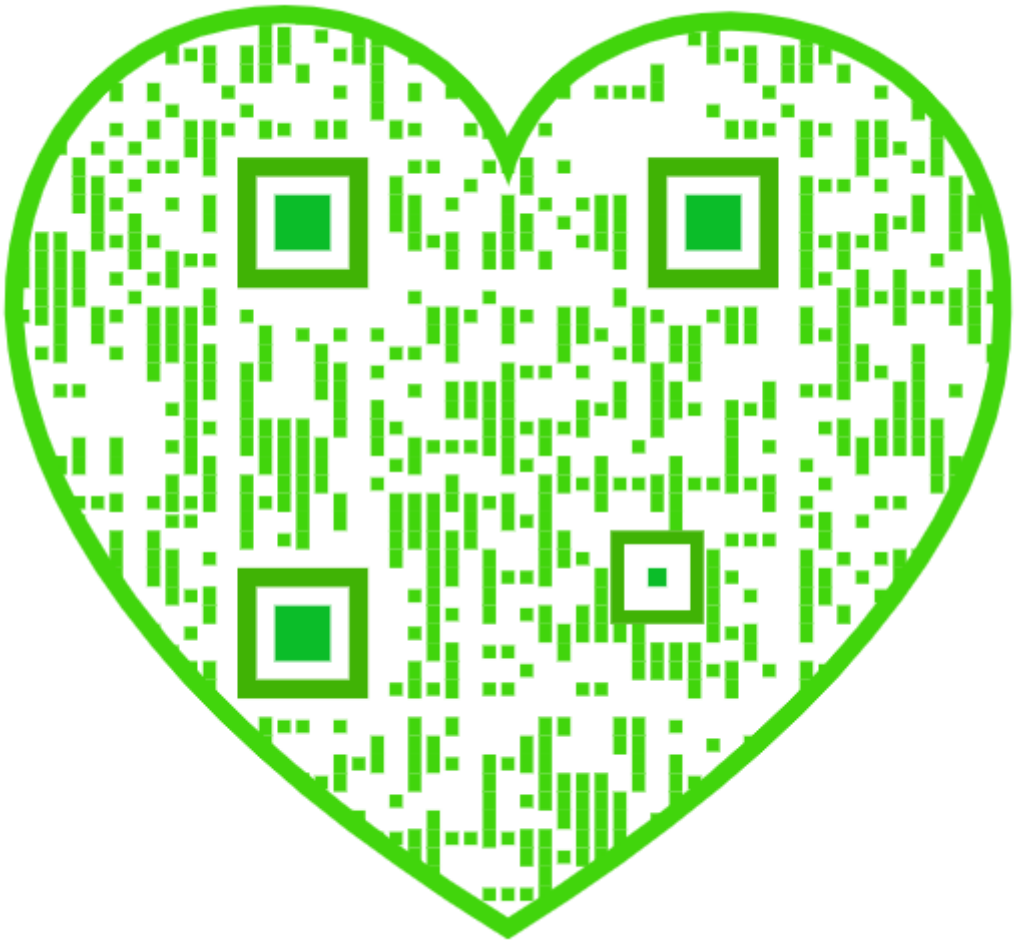

THE RUDIMENTS OF

MINERALOGY

A CONCISE VIEW OF THE GENERAL PROPERTIES OF MINERALS

BY

ALEXANDER RAMSAY, F.G.S., F.R.G.S., ETC.

Third Edition, Revised and Enlarged

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PREFACE.

THE following treatise is an attempt to bring together the more important facts relating to the general properties of minerals in as concise a form as possible.

Numerous works and articles have been consulted. It would not be desirable to give a list of all of them, but those to which the writer has been most indebted are Rammelsberg's "Mineralchemie," De la Fosse's "Minéralogie," Bischof's "Chemical and Physical Geology," and Des Cloizeaux's "Minéralogie."

The prominent features of the treatise are the arrangement of the minerals, which is nearly the same as that adopted for the mineralogical collection in the British Museum by Professor Maskelyne; the employment of the new atomic weights; the recog-

nition of the principles of isomorphism and atomicity in the construction of most of the formulæ; and the reduction of the specific gravities to a single scale of which hydrogen is the unit.

In the present edition the work remains substantially the same as before, but numerous additions and alterations have been made whereby the volume has been increased about thirty pages.

A. RAMSAY.

August, 1885.

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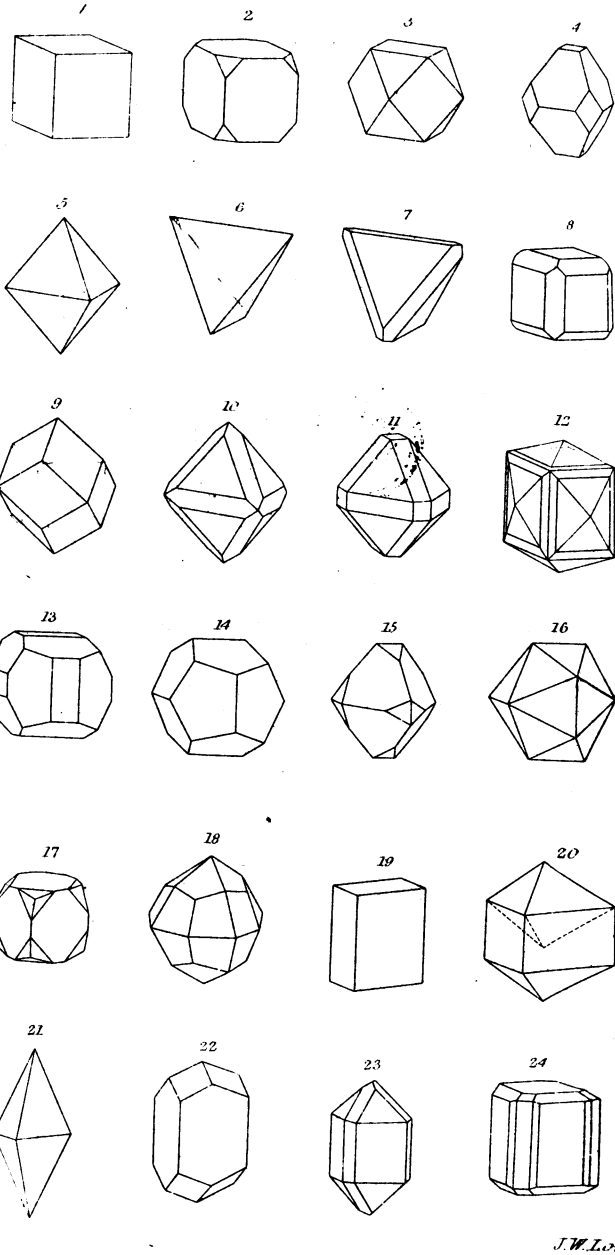

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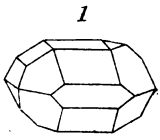
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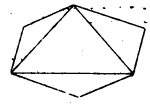
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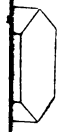

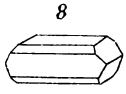
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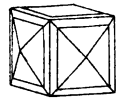
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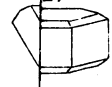
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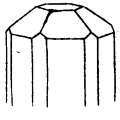
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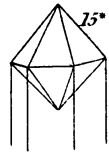
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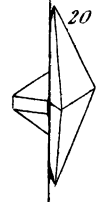
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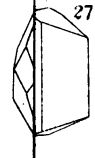
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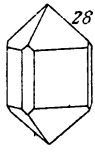
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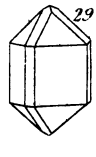
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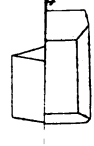
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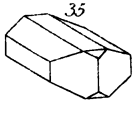
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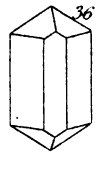
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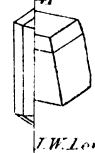
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MINERALOGY.

CHAPTER I.

INTRODUCTORY.

MINERALOGY* is the science which embodies the laws and facts relating to a certain group of objects, called *minerals;* but what a mineral is does not admit of an easy and strict definition. Dana defines it as "any substance in nature, not organised by vitality, which has a homogeneous structure;" and De la Fosse as a naturally formed inorganic body constituting part of the earth. Neither of these are satisfactory, for the first includes all the artificial products, such as alcohol, glycerin, and sugar, formed in the laboratory of the chemist, the study of which is certainly never considered to be the special province of the mineralogist. It also assumes that all the hard parts of plants and animals are moulded and shaped by a vital force, and consequently determines that the arragonite of shells, and the *raphides* or crystals of oxalate of lime in plants, are not minerals. The second definition appears to exclude meteorites and the minerals found in them. There is, indeed, no natural group of substances which can be satisfactorily included in any definition of mineral, but

* Mr. Tomlinson, in his "Introduction to the Study of Natural Philosophy," in this series, thus defines the terms *Geology* and *Mineralogy;* the first as having for its object the observation and description of the structure of the external crust of the globe, and the second as confining itself to the account of the separate items of which that crust is composed.

the following appears to be the best that can be formed at present. By a mineral is meant any chemically homogeneous substance which neither forms, nor retains any traces of having formed, part of an organised being, and which has not been produced by the application of physical forces by man. So long then as elements and their compounds answer to this description they are the objects which the mineralogist studies; when they occur in plants and animals the physiologist, botanist, and zoologist investigates their properties; and when they are laboratory products they belong to the science of chemistry. The distinction is, therefore, simply a conventional one, and is based not on any essential difference in the substances themselves, but on the different circumstances by which they are surrounded. When two or more minerals occur together and form large masses, they constitute *rocks*, the description and study of which is the especial object of the science of *lithology*.

The properties of minerals are numerous. Some, such as the form, bulk, hardness, colour, &c., are readily perceived; while others, such as chemical nature, crystalline structure, behaviour towards light and heat, are not so apparent, and can only be determined by means of a systematic investigation. The value of these properties in affording distinguishing characters differs greatly, but the most important are chemical composition, crystalline form, and density.

From the foregoing remarks it will be seen that the study of minerals involves a more or less extensive knowledge of chemistry, optics, and other physical sciences. Our space forbids that any attempt be made to give even a rudimentary outline of all these sciences, and indeed such a course is quite unnecessary, since several treatises in this series are devoted to these subjects. But it may not be out of place to give a rapid outline of a few of the more important principles which illustrate the nature of minerals.

All matter has weight; the same quantity of matter always has the same weight, and the same substance

always has the same volume and weight under the same circumstances. The density is in inverse proportion to the volume; and the latter is augmented by a relative increase in the repulsive forces acting upon the particles of the substance, and diminished by an increase in the molecular attractive forces or of the external pressure. In short, density is an indication of the amount of force to which a body has been, or is being, subjected. These axioms, as they might be called, appear to be a few of the fundamental principles of chemistry, but, nevertheless, they do not seem to have had the importance attached to them which they deserve. For example, the weight of 11·19 litres (19·69 pints) of hydrogen at the temperature of 32° F., and under the ordinary atmospheric pressure which corresponds to 30 inches of mercury, is 1 gramme (15·44 grains). So long as the force of gravitation remains the same the weight of this quantity of hydrogen will never alter, even if it should be made to occupy a space a thousand times smaller, or a thousand times larger. And it must be carefully remembered that all the figures and results in the following pages which relate to weight are only true so long as the force of gravitation remains at its present intensity. There is even a difference according to the latitude, but it may be disregarded, since the error which it involves is exceedingly small. Hydrogen is well known as the lightest of all substances, and as the nearest approximation yet detected to what the physicist calls a perfect gas, that is, an aeriform body which expands at a uniform rate for equal additions of heat. In defining what will be repeatedly referred to as the unit of hydrogen, special degrees of temperature and pressure were mentioned, because if these be altered the volume will be changed. Suppose then the temperature be raised while the pressure remains the same. The gas will not only become warmer, but will acquire greater volume. Thus, if the unit of hydrogen be heated from 32° to 212° F., the 11·19 litres (19·69 pints) will expand to 15·28 litres (26·89 pints), but the weight will still be 1 gramme. The

heat absorbed by the hydrogen has produced two effects which should be carefully distinguished. First, it has expanded the gas, and, next, it has raised the temperature; which two points will be considered separately. A volume of 19·69 pints is equal to 682 cubic inches, and that of 26·89 pints corresponds to 932 cubic inches. If, then, the hydrogen were placed in a tube with a bore 1 sq. in. in area, and this tube were connected with a second similar to the first, but containing a vertical column of 30 inches of mercury surmounted by a long Torricellian vacuum, it would occupy a space of 682 inches at 32° F. By the time it had attained 212° F. it would occupy a space of 932 inches: and consequently will have raised the 30 inches of mercury through a height of 250 inches or 20·8 feet. This is equivalent to the raising of 14·68 lbs. (the weight of the mercury) to a height of 20·8 feet, or 305·34 lbs. to the height of 1 foot; or, as it is usually expressed, 305·34 foot-pounds.*

This represents only a portion of the heat taken up by the hydrogen, the remainder having been spent in raising the temperature, In order to ascertain what proportion is required for this purpose, the expansion of the hydrogen must be prevented so as to keep the volume constant. This might be done by placing weights on the gas. Under these conditions less heat would be required to raise the temperature to 212° when the volume is constant than when the pressure is constant, in the proportion of 1 to ·414. When the gas is allowed to expand, a quantity of heat is taken up which may be represented by 1·414; and when expansion is prevented the quantity is 1. The expansive force then clearly corresponds to the quantity

* As we shall have frequent occasion to compare the work done by hydrogen when expanding under the constant pressure of 30 in. of mercury, it will be convenient to consider the work-unit for hydrogen to be the quantity performed by 1 gramme when heated from 0° C. to 1° C. (32° F. to 33°8 F.), viz., 3·05 ft.-lbs., and the heat-unit will be the quantity of heat absorbed by the gramme of hydrogen when heated from 0° to 1° C. The heat then required to raise 1 gramme or unit weight of hydrogen from 32° to 212° under constant pressure would be 100, and when the volume is constant it would be 70·7.

of heat represented by ·414; but it has already been found that this force is equal to 305·34 foot-pounds, and consequently it is also represented by ·414 of heat. From these data it is easy to find the amount of force corresponding to the different quantities of heat. Thus, ·414 = 305·34 foot-pounds; 1 = 737·5 foot-pounds; and 1·414 = 1042·84 foot-pounds. When then 1 gramme of hydrogen expands from 11·19 litres at 32° to 15·28 litres at 212°, it absorbs a certain quantity of heat; of this quantity 70·7 per cent. is used for heating, and 29·3 per cent. for expanding.

In the above cases the temperature has been the inconstant element; and there remains to be considered the effects produced by varying the pressure, and keeping the temperature constant. When the pressure is increased, the density is increased in proportion; and it may be considered as a rule generally applicable to hydrogen, oxygen, and all perfect gases, that their density is inversely as the pressure. Thus, if we call the unit volume of hydrogen 1, a pressure of two atmospheres or 60 inches of mercury will reduce its volume to $\frac{1}{2}$, and increase its density to 2; with three atmospheres the volume will be $\frac{1}{3}$, and the density 3, and so on. The effect of the increased pressure is to force more matter into a given volume, say 11·19 litres, and consequently to increase the weight of such volume; in short, the greater the density, the greater is the quantity of matter in the same space. So that when hydrogen is subjected to a pressure of six atmospheres, or 87 lbs. on the square inch, 11·19 litres contain 6 grammes, or six times as much as the 11·19 litres under a pressure of 1 atmosphere. On the other hand, the density is reduced to $\frac{1}{2}$ when half the pressure is removed, and to other degrees according to the reduction of the pressure. The pressure which would be required to cause the unit volume of 11·19 litres to expand to 15·28 litres is therefore 14·5 lbs. $\times \frac{11{\cdot}19}{15{\cdot}28}$ or 10·6 lbs., a pressure which corresponds to about 21 inches of mercury. This result is, therefore, brought about by removing

9 inches of mercury, and the expansion by one-hundredth part, or from 11·19 litres to 11·28 litres is brought about by a reduction of ·09 inch in the height of the mercury.

These facts lead to the important conclusions that in perfect gases equal additions of temperature or of pressure produce equal proportional effects, and that what temperature does, pressure counteracts so far as expansion is concerned. In short, we have a balance by which we can compare the relative intensities of different kinds of force analogous to the ordinary balance by which we compare the relative weights of different quantities of matter. The gas expands by the addition of heat or the subtraction of pressure, and it contracts by the subtraction of heat or the addition of pressure. For each hydrogen unit of heat taken up it expands by $\frac{1}{273}$ of its bulk, and becomes 1° C. warmer; and for each weight-unit it contracts by $\frac{1}{273}$ of its bulk. The weight-unit then is, as we have before indicated, less than the heat-unit, inasmuch as the heat-unit expands and warms, while the weight-unit counteracts the expansion only. We may express this by equations. Thus, 1 gramme of hydrogen + 1 heat-unit = 1 gramme of hydrogen + 1 weight-unit + 1° C., or 1 gramme of hydrogen + 10·428 ft.-lbs. = 1 gramme of hydrogen + 3·05 ft.-lbs. + 7·37 ft.-lbs. Therefore the heat-unit equals 1 weight-unit + 1° C., and the weight-unit equals the heat-unit — 1° C. If then the gas is expanded from 11·19 to 11·23 litres, and has its temperature raised from 0° to 1° C. by the expenditure of heat force corresponding to 10·428 ft.-lbs., we have the state represented in the equation; and, supposing the gas was under constant pressure, it follows that if an additional force of 3·05 ft.-lbs. be added to the pressure the gas will be reduced to its original bulk, and the heat used for expanding the gas will be liberated. This quantity of heat is represented by the 3·05 ft.-lbs., and would be sufficient to raise the temperature of the 11·19 litres of hydrogen from 0° to ·414°.

All matter resembles hydrogen in possessing most of

the above properties, such as expanding when heated, and contracting when cooled; but there are some substances which, at certain temperatures, expand when cooled and contract when heated. These exceptions, which include water, bismuth, amorphous antimony, amorphous sulphur, amorphous selenium, iodide of silver, and a few other substances, will not appear to be quite so anomalous, if it be remembered that heat is not simply an expanding force when applied to elementary liquids and solids. In these substances the density does not depend solely on heat or pressure, but chiefly on a third force usually known as cohesion; while in compounds there is still another contracting or uniting force known as chemical affinity. In addition to these there are other forces, such as magnetism, which appears sometimes to act as an expander, and electricity, which is a powerful counteractor of chemical affinity. It is known that the intensity of some of these does not bear the same direct relationship to that of heat, as is observed between heat and pressure, and hence it is possible that at certain temperatures the contracting forces may diminish more slowly than the expanding forces are increased when the substance takes up an additional supply of heat. The line of inquiry thus suggested would, if followed up, probably afford some explanation as to why different elementary substances have different densities or specific gravities at the same temperature and under the same pressure. This difference is strikingly shown by the column in the table at pp. 24, 25, which gives the specific gravity of the elements according to the hydrogen scale. As will be presently shown, the relative weights of gases and vapours have an intimate connection with their chemical nature, and probably there is an equally intimate connection between these two properties in solids and liquids; but it has not yet been demonstrated on account of the difficulty of distinguishing between the specific gravity due to the chemical nature, and that due to the molecular condition of such substances. Notwithstanding this, the specific gravity of minerals is an exceedingly impor-

tant character. If every mineral were absolutely pure its specific gravity would be the same in all specimens under similar circumstances as regards temperature and pressure. But as there is a certain range in their composition, so there is a certain range in their specific gravity; and hence it is that in describing minerals this range is generally mentioned. In minerals having the constitution of common salt (NaCl) there is no room for any variation in constitution, and there is scarcely any variation in their specific gravity; but in more complicated minerals the range may be considerable. Still the character is a sufficiently marked one to enable the student to readily distinguish most minerals having a similarity of colour and appearance. The specific gravity is ascertained by first weighing the mineral in water, then in air, and by dividing the last result by the difference between the two. The rationale of this process will be understood by remembering what is done in ordinary weighing. A brass weight being placed in one scale, may be counterbalanced by a similar weight in the other. If a gold weight of similar size were substituted for the latter, several brass weights would be required to counterbalance it. In other words, the specific gravity of gold is greater than that of brass. Suppose then water be used instead of brass, and suppose that a vessel be used having a capacity of one pint. If this be filled with water, the water will weigh about 20 ounces; if it be filled with fine sand, the weight of the sand will be about 52 ounces; and the proportion between the two weights is as 1 to 2·6, which numbers represent the specific gravity and relative weights of the two substances. This method would be inconvenient for most solids, and hence the ordinary process is resorted to. When the body is immersed in water it displaces its own bulk of that liquid, and its weight in such circumstances is its absolute weight less the weight of the bulk of water of which it occupies the place; when weighed in air the weight is the absolute weight less that of its own bulk of air. As the air displaced has an almost inappreciable weight, this is disregarded; and hence we have the absolute weight of the substance and the same

weight lessened by that of a similar bulk of water. The difference is clearly the weight of the water, and if this be called 1, it will, when divided into the absolute weight, give a quotient representing the relative weights or specific gravities.

The chemical composition of minerals is a highly important character. The chemist is acquainted with about 60 elementary substances, that is, substances which have not, as yet, been split up into two or more other substances possessing different properties. All bodies known to the chemist are composed either of the elements themselves or of combinations of them. Amongst the elements which occur in the native state may be mentioned oxygen, carbon, copper, gold, and platinum, while most of the minerals are examples of compounds. If the reader glances through the following descriptions he will notice that, generally speaking, the simpler compounds are described first. Hydrochloric acid (HCl) is among the earliest mentioned, and as this is one of the *types* of chemical compounds, we will examine its properties and nature a little closer. H and Cl are the symbols or short expressions for *H*ydrogen and *Cl*orine; every element has its symbol, as shown in the table at pp. 24, 25, and HCl indicates that the two are chemically united. Both are gases, but the one is much heavier than the other. This relationship in weight is expressed in many ways. Thus, if we weigh similar volumes, say 100 cubic metres, when the temperature is about 60° F., and the atmospheric pressure counterbalances 30 inches of mercury, we find that the hydrogen is equal to 2·15 grains, and the chlorine to 76·6 grains, or in the proportion of 1 to 35·6. The same relation may also be expressed by referring their relative weights to that of a similar bulk of air under the same conditions. Thus, if the air weighs 1 lb., the hydrogen will weigh ·0692 lbs., and the chlorine 2·47 lbs., which numbers represent the specific gravity of these substances, air being unity; but if hydrogen be selected as unity, then H would be 1 and Cl = 35·5, which numbers also represent the weights of the smallest combining pro-

portions of hydrogen and chlorine, or, as they are generally called, the atomic weights. The theory of atomic weights, however, involves something more than this, viz., that bodies always combine in a definite proportion, or some multiple thereof. Thus, if we place a volume of hydrogen and a volume of chlorine in the same vessel, and expose them to direct sunlight or to flame, they will combine with a loud explosion. None of the hydrogen or chlorine will remain uncombined; but if originally the proportions of the two gases had been slightly unequal, the excess above the volume would remain uncombined. When hydrogen or chlorine are combined, either with themselves or with other substances, it is always in the proportion of one, two, or several volumes, and never in any fractional proportions, such as $2\frac{1}{2}$, $3\frac{1}{4}$, &c. This principle is the basis of the great discovery of Dalton, known as the law of combination in definite and multiple proportions. For the purpose of illustration we have used the word *volume*, as that implies no hypothesis as to the constitution of matter; but Dalton used the word *atom*, by which he meant a particle of matter incapable of being divided either physically or chemically, which did involve an hypothesis, seeing that nothing was, or indeed is, known as to the ultimate composition of matter. It is possible that the chemical atom may be composed of several physical atoms. The word atom, as used by chemists now, simply means the smallest known combining proportion of a body, without any reference to indivisibility, while *molecule* is the term given to the smallest cluster of atoms capable of self-existence. The word *unit* is also sometimes employed with the same meaning, and seems to be preferable to any yet mentioned. The H then stands for 1 atom, unit, or volume of hydrogen, and in the same way the symbols of all other substances stand for 1 atom, unit, or volume. If there are two or more atoms or volumes, it is indicated by a small number; thus H_2 = 2 volumes of hydrogen, H_3 = 3 volumes of hydrogen, and so on. Hydrochloric acid is, as we have said, HCl. There are two ideas implied in this, which should be carefully dis-

tinguished in all chemical formulæ. First, it implies that with every grain weight of hydrogen there is combined 35·5 grains of chlorine. This is a matter of direct experiment, and is easily ascertained. It also implies that hydrochloric acid is composed of 1 volume of hydrogen and 1 volume of chlorine; this is a matter far more difficult of proof, and necessitates a comparative analysis of all the other bodies known to contain either of them. This point is well illustrated in the case of water. Chemists have long admitted that the proportion by weight between the hydrogen and oxygen of which it is composed is as 1 to 8. In accordance with this the formula HO was adopted, which it will be noticed implies that they are combined in the proportion of atom for atom. Suppose we admit this, then the atomic weights of H = 1, of Cl = 35·5, and of O = 8. If what we have said above be true, it will follow that the volume of hydrogen which combined with chlorine to form hydrochloric acid, will combine with 1 volume of oxygen to form water. The experimental test does not confirm this view, as the result of the attempt to combine equal volumes of these two gases is water plus half a volume of oxygen. In other words, oxygen will never combine with less than twice its own volume of hydrogen. There is a substance, the peroxide of hydrogen, whose formula is frequently written HO; and this would appear to be directly opposed to the above statement. This formula does not truly represent peroxide of hydrogen, which is H_2O_2. The difference between the two is an important one, and should be expressed in all formulæ, although it is frequently not indicated. By HO is meant that 1 volume of hydrogen and 1 volume of oxygen are combined to form 2 volumes of a protoxide of hydrogen; by H_2O is meant that 2 volumes of hydrogen and 1 of oxygen are combined into 2 volumes of steam; and by H_2O_2 that 2 volumes of hydrogen and 2 volumes of oxygen are condensed into 2 volumes of a peroxide of hydrogen. If all these bodies were known in the gaseous state, HO would be lighter than H_2O, and this in its turn would be lighter than H_2O_2, and,

under certain conditions, which cannot be mentioned here, the same would be the case if all the bodies were known in a liquid form. The specific gravity of liquid HO, if it were known, would be less than 1; that of H_2O or water is 1; and that of peroxide of hydrogen, or H_2O_2, is 1·45. Again, the O in HO is indivisible, but peroxide of hydrogen is remarkable for the facility with which it parts with half its oxygen. Whether water be formed by synthesis or decomposed by analysis, its composition is always 2 volumes of hydrogen and 1 volume of oxygen. The conclusion then is that the molecule of water contains twice as much hydrogen as hydrochloric acid. If then the latter is HCl, the former should be H_2O. There are many confirmations as to the correctness of this latter view, and one of these is that the proportion between the specific gravities of the two gases is the same as between their atomic weights, viz., as ·0692 : 1·1056 or as 1 : 16. This similarity in the proportions probably obtains between the specific gravities of all substances in a gaseous state and their atomic weights. It may then be considered as almost certain that in hydrochloric acid the H and Cl are combined atom for atom. There are many other elements which combine atom for atom, and are hence distinguished as *monatomic* elements. A list of them is given further on (p. 26). Compounds having this constitution are represented by such minerals as common salt, and several others described in Chapter V.

Water is another primary chemical type, and is composed of 2 atoms of hydrogen to 1 of oxygen. Oxygen and all elements which, like it, combine with 2 atoms of hydrogen, or any other monatomic substance, are said to be *diatomic*. There are many compounds having this constitution; for example, *argentite* is Ag_2S; cuprite Cu_2O. Water may be represented either by H_2O, or HHO, and any of the 3 atoms may be replaced by another of the same degree of atomicity as itself, or the 2 atoms of hydrogen may be replaced by 1 atom of a diatomic element. A simple illustration of this occurs when potassium is thrown on water. The potassium (K) takes fire, hydrogen is

liberated, and hydrate of potash is formed. Expressed chemically, the process is this. Water being HHO, the potassium turns out 1 atom of hydrogen and takes its place; or

$$\underset{\text{(water)}}{HHO} + \underset{\text{(potassium)}}{K} = \underset{\text{(hydrate of potassium)}}{HKO} + \underset{\text{(hydrogen)}}{H}.$$

The second atom of hydrogen may be turned out by exposing 1 atom of the hydrate and 1 atom of potassium to a high temperature. The process is

$$\underset{\text{(hydrate of potassium)}}{HKO} + \underset{\text{(potassium)}}{K} = \underset{\text{(potash)}}{KKO} + \underset{\text{(hydrogen)}}{H}$$

By suitable means the O may be replaced by a diatomic element, such as sulphur, S; but as the process is a complicated, indirect one, the details will not be given. Suffice it to say that the atomic weights or combining proportion given in the table, explains difficulties which could not be satisfactorily surmounted by the numbers in use a few years ago. We have already given experimental tests which support the accuracy of H_2O as the formula for steam. And now we will try another. If HO is right, the potash experiment shows that we can divide H into two smallest combining proportions, which is an absurdity if the meaning of the word, atom, is accepted as defined above; but if H_2O is right, it is quite consistent, as the experiment only proves the divisibility of a molecule or 2 atoms of hydrogen. If then the atomic weight of hydrogen is 1, that of oxygen is 16, and water is composed of 2 parts by weight of hydrogen, and 16 parts by weight of oxygen. There is yet another test, viz., the specific gravity. As a rule the monatomic gases combine volume for volume to form a compound composed of 2 volumes. Hence, in order to find their specific gravities, it is only necessary to add their atomic weights together, and divide by 2. Thus $H = 1 : Cl = 35{\cdot}5 = \frac{36{\cdot}5}{2} = 18{\cdot}25$; but as air is usually taken as the standard and not hydrogen, this number must be multiplied by the specific gravity of hydrogen: we then

have 18·25 × ·0693 = 1·265. According to experiments it is 1·27. In the second class of bodies formed upon the type H_2O, the 3 volumes of gas combined form a compound which in the gaseous state has a bulk of 2 volumes, consequently there has been condensation. The atomic weight of H being 1, and of O 16, $H_2O = 18$, the specific gravity of steam will be $\frac{18}{2} \times ·0693 = ·623$. According to experiments it is ·625. The slight differences observable between the results of calculation and experiment are in most cases due to a want of strict comparability of the surrounding conditions. However the results are sufficiently close for our purpose, which is to show that the formula H_2O, is preferable to HO, and that every formula ought to be in harmony with both the physical and chemical properties of the substance. The specific gravity of $H_2O = 18$, as we have seen, is ·62, or that of steam: while that of HO = 9, if it existed, would be ·31. The specific gravity is, in fact, a test of the accuracy of a formula, and may even be employed as a means of ascertaining what the formula is. Thus under sulphuretted hydrogen the specific gravity is said to be 1·178; hydrogen we know is a monatomic element, and sulphur is a diatomic one. The simplest possible combination is when 2 volumes of the one and 1 volume of the other combine to form 2 volumes of a compound. In order to find out the constitution of the body, we must reverse the process by which the specific gravity was deduced from the formula. Thus we divide 1·178 by $\frac{·0693}{2}$ and the result is 34·90. On referring to the table of atomic weights, we find S = 32, and H = 2, leaving a surplus of ·9, which is partly due to the atomic weights not being expressed with absolute correctness. The atomic weight of hydrogen is so small that it appears doubtful, in this instance, whether there are 2 or 3 volumes of hydrogen; but where the atomic weights of the elements are greater, this difficulty is not met with.

Ammonia (H_3N) is another chemical type, and

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similar arguments might be brought forward in support of its being H_3N, and not H_6N_2, or $H_3^2N_1^1$, all of which are equally consistent with the fact that ammonia is composed of 83·39 per cent. by weight of nitrogen, and 17·61 per cent. of hydrogen; but the latter two are inconsistent with the fact that the hydrogen in ammonia can be divided into three parts, and as far as the chemist knows at present, into three parts only. The first, also, is the only one which harmonises with the specific gravity. Thus $\frac{3 \times 14}{2} \times ·0693 = 5·89$, while the results obtained by Davy and other experimenters, vary from 5·90 to 5·96. In the formation of ammonia the 3 volumes of hydrogen and 1 volume of nitrogen are condensed into 2 volumes of ammonia. In ammonia, as in the previous types, each atom may be replaced by another of the same degree of atomicity as itself; thus the hydrogen may be replaced by one, two, or three monatomic atoms or radicles, or the N may be replaced by a triatomic atom; or several molecules of ammonia may be concerned, in which case a given amount of atomicity represented by hydrogen and nitrogen may be replaced by a similar amount of atomicity represented by other elements. Examples of this abound in organic chemistry, but are comparatively rare amongst minerals; nevertheless, the same law prevails in both organic and inorganic compounds. The triatomic elements are arranged in the table (p. 26), along with nitrogen.

Marsh gas (H_4C) is another type. It is composed of 4 volumes of hydrogen and 1 volume of carbon, and still the volume of marsh gas is only twice that of free hydrogen. Its specific gravity is sufficient to confirm this statement, for the atomic weight of carbon being 12, we have $\frac{4 + 12}{2} \times ·0693 = ·5544$, which closely accords with the result of experiment, viz., ·5576. Compounds of this type are exceedingly abundant in organic chemistry, but there are some minerals which represent it; and these enter into most of the species known to the mineralogist. Carbonic acid (CO_2) is one of them, and silica ($Si O_2$) is another. There are

a few elements which appear to be pentatomic, hexatomic and heptatomic.

We have hitherto spoken of the degree of atomicity as if there were no exceptions to the rule laid down. There are some, but whether apparent or real is not known. It scarcely comes within the province of a rudimentary treatise to point out these anomalies. One of them is that the same element may combine with an odd or an even number of atoms of chlorine, as in the case of iron, copper, and a few more. Thus we have FeO or ferrous oxide, in which iron is diatomic, and Fe_2O_3 or ferric oxide, in which it is triatomic. These are difficulties which are variously explained by chemists; but as yet the true solution does not appear to have been started, unless it be that the combining proportion is intimately connected with the relative densities of the elements at the moment of combination.

In the following table the atomic weights which best conform to modern researches are given. The student must not look upon them as absolute truth, but simply as the best known as yet. Probably, in the course of a few years, circumstances will require the alteration of some of them.

In the description of most of the minerals, the student will notice a formula, followed by a *per-centage composition*, that is, the weights per cent. of the various constituents. Thus *stephanite* is headed by $6Ag_2S.\ Sb_2S_3$ or Ag = 71·1. Sb = 13·1, S = 15·8. In this, as in all similar cases, the formula is to a certain extent hypothetical, and the per-centage composition simply represents what would be the composition of a pure mineral having this formula. There is one great defect in all the formulæ for liquid and solid minerals, inasmuch as they only represent the proportions in which the elements are present, and not their degree of condensation. Minerals are seldom or never absolutely pure, and consequently an actual analysis will not precisely correspond with the figures given by the formula. By impurity we here mean chemical impurity not the mechanical admixture of dirt and other foreign

substances. For instance, the following are analyses of *stephanite* by Rose and Kerl:—

	Rose.	Kerl.
Sulphur	16·42	16·51
Antimony	14·68	15·79
Silver	68·54	68·38
Copper	·64	—
Iron	—	·14

Neither of these, it will be noticed, perfectly agree. The copper and iron are present in small quantities only, and have in all probability replaced a portion of the silver. If twenty analyses had been given, the same minor differences would be seen. These differences may be due partly to the impurity of the specimens, and partly to the want of accuracy on the part of the analysers. In a full treatise on mineralogy it would be desirable to give a number of analyses of each substance, in order that the student might work out the formula for himself, but in a small treatise this is impracticable; so that the only course is to give the supposed composition of the pure mineral. The way in which formulæ are constructed from analyses is as follows: the atomic weight of the element is ascertained, and the number in the analysis is divided by it. Thus, in the case of *stephanite*,—

$$\text{Sulphur S} = 32 \text{ and } \frac{16{\cdot}42}{32} = {\cdot}51$$

$$\text{Antimony Sb} = 122 \text{ and } \frac{14{\cdot}68}{122} = {\cdot}12$$

$$\text{Silver, Ag} = 108 \text{ and } \frac{68{\cdot}54}{108} = {\cdot}63$$

A comparison of its crystalline forms and general behaviour before the blowpipe with those of *pyrargyrite*, points to the probability of its being, like that mineral, a sulphantimonite of silver. The selection of the best formula is always an exercise of the judgment, especially in the case of complicated minerals. In *pyrargyrite* the number of atoms of antimony is 2, and the adoption of the same number of atoms for *stephanite* evidently facili-

tates the construction of a formula. If antimony be 2, then the proportion as above given should be doubled and consequently all the others will require to be doubled. The formula which answers best for these proportions is $6\,Ag_2\,S\,Sb_2\,S_3$. In simpler cases the process is much easier: thus, according to various chemists, *galena* was found to contain the following proportion of ingredients:—

	(1) Westrumb.	(2) Lerch.	(3) Thomson.
Lead	83·00	81·80	85·13
Silver . . .	·08	——	——
Iron	——	——	·50
Zinc	——	3·59	——
Sulphur . .	16·41	14·41	13·02
	99·49	99·80	98·65

The silver, iron, and zinc are clearly non-essential to pure galena, and there is an evident want of uniformity in the analyses. The atomic weight of lead is 207 and $\frac{83}{207}$ = ·4 nearly; and $\frac{16{\cdot}4}{32}$ = ·5. Considering that the analyses do not show any evidences of the purity of the specimens experimented upon, the probability is that the elements are combined in equal atomic proportions. The formula then is PbS, which is known to be the true formula, since *galena* can be formed artificially.

It is often desirable to ascertain what the per-centage composition of a mineral is when the formula is known. By way of illustration we will convert the formula of *galena* and *stephanite* into their per-centage compositions. The method is to add up the atomic weights of all the elements, and then to work out the number to be allotted to each by proportion. Thus, PbS = 207 + 32 = 239. The proportion of lead is as much less 100 as 207 is less than 239; or

$$\text{As } 239 : 208 :: 100 : x = 86{\cdot}6.$$

The remainder 13·4 per cent. is of course sulphur. The same process is followed in the case of *stephanite*; here

there are 12 atoms of silver, 9 of sulphur, and 2 of antimony.

Antimony	= 122 × 2	=	244
Sulphur	= 32 × 9	=	288
Silver	= 108 × 12	=	1296
			1828

On working out the various proportion sums we get antimony = 13·1; sulphur = 15·8, and silver = 71.1.

Although we have already devoted so much space to the chemical branch of mineralogy, and a great deal more might be said, we cannot entirely pass over the subject of *isomorphism*, a law of great importance in mineralogy. By isomorphism is meant the similarity in crystalline forms presented by bodies having similar chemical constitutions. There are many examples, but perhaps the best known form the group of carbonates to which arragonite belongs, as given below.

Name.	Composition.	Terminal angle of right rhombic prism.
Arragonite	CO_2 CaO	116° 10′
Witherite	CO_2 BaO	118° 30′
Strontianite	CO_2 SrO	117° 19′
Cerusite	CO_2 PbO	117° 14′

		Terminal angle of obtuse rhombohedron.
Calc Spar	CO_2 CaO	105° 3′
Magnesite	CO_2 MgO	107° 25′
Dolomite	CO_2 Mg : CaO	106° 15′
Mesitine Spar	CO_2 Mg : FeO	107° 14′
Chalybite	CO_2 FeO	107°
Diallogite	CO_2 MnO	106° 51′
Calamine	CO_2 ZnO	107° 40′
Barytocalcite	CO_2 Ba : CaO	106° 54′

In each of these groups the angles of the crystals vary very slightly, so slightly that as regards the general form of the crystal it does not matter whether calcium, magnesium, manganese, iron, barium, zinc, or lead, is the metal present. These elements all belong to the diatomic

series, and may replace each other in any proportion without materially altering the form of the crystal. Hence these elements, or the carbonates into which they enter, are said to be isomorphous. We cannot follow out this law into all its ramifications in order to show how peroxides replace peroxides, and protoxides replace protoxides; how by this process of substitution, which is constantly though slowly going on in nature, one mineral species is converted into another; how by substitution and loss, rocks, which are aggregates of minerals, are completely altered in nature, but must content ourselves with hinting that such phenomena do exist, and that their investigation is one of the most interesting branches in the whole range of mineralogical science. There is reason to believe that peroxides may be replaced by protoxides, and protoxides by peroxides, and it is in accordance with this belief that many of the formulæ of the silicates in this treatise have been formed. These formulæ are simpler than those usually given, and represent the true proportion of the elements, but not their actual volumes. Thus, *spessartine* is represented by $Mn : Al\ SiO_4$ and *pyrope* by $(Al : Cr : Ca : Fe : Mn : Mg)\ SiO_4$. The substances separated by colons are supposed to be isomorphous, and the whole of them put together suffice to combine with two atoms of oxygen, the silicon requiring the other two. Manganese is a diatomic, and aluminium a triatomic element; so that in pure *spessartine* the proportion of oxygen belonging to them would be as 1 to 3. It might be written $(\frac{1}{3}\ Mn\ Al\ Si\ O_4)$; but this formula would not then answer for specimens in which substitution has taken place. In all these formulæ the proportion of oxygen indicates at once the per-centage composition of the pure mineral. One advantage attending this method is that the relationship in chemical composition is more clearly shown.

The specific heat of bodies is, like specific gravity, an important aid in determining their physical constitution. In referring to the relations between weight and matter, it was said that all matter has weight, and that the same

quantity always has the same weight. A similar statement might be applied to heat, but it would not have the same general application, since carbon, boron, and a few other elements would be exceptions. Bearing those exceptions in mind, a few details may be given respecting some of the relations between heat and matter. In an earlier page mention was made of the effects of heat on hydrogen, and it was stated that a definite quantity of heat was required to raise 1 gramme (15·44 grains) from 0° to 1° C. under a constant pressure of 30 inches of mercury. This quantity is represented by the mechanical force of 10·4 ft.-lbs. For the sake of convenience we shall adopt this as a unit, although in most books the quantity required to heat a given bulk of air or water to the same extent is usually adopted. The figures deduced from the hydrogen standard are always placed in parentheses.*

By specific heat is meant the relative quantities of heat which different bodies absorb when their temperature is raised by the same amount. Thus, if a pound of mercury and a pound of water having the same temperature be heated for, say ten minutes, by the same source of heat, and in a situation equally favourable for both to take up the heat, it will be found that the temperature (as marked by the thermometer) of the mercury will be much greater than that of the water; in other words, the water requires more heat than mercury to raise its temperature through the same number of degrees. This quantity varies according to the state of the substance and with different substances. If 1 gramme of hydrogen at 0° C. (32° F.) and under a pressure of 30 inches of mercury, requires the quantity of heat represented by 10·4 ft.-lbs. to raise

* The English unit of heat is the quantity required to raise 1 lb. of water from 60° to 61° F., the equivalent of which in work is 772 ft.-lbs. If this be reduced so as to harmonise with the hydrogen unit, we shall find that 1 gramme of water is raised from 0° to 1° C. under constant pressure by a quantity of heat equivalent to 3·05 ft.-lbs., which it will be noticed is to 10·4 ft.-lbs. as 1 to 3·4, the latter number being the specific heat of hydrogen according to the water scale.

its temperature 1° C., it will require a smaller quantity to effect the same result when the pressure is increased by 30 inches of mercury, or 1 atmosphere; still less when it is increased still more; and hence the specific heat of hydrogen under high pressure, or of high specific gravity, is less than that of hydrogen of low specific gravity. What is true of hydrogen will apply generally to all substances, so that as a rule substances of high specific gravity have a low specific heat, and *vice versâ*. But this rule cannot be applied strictly, for the specific heat does not bear any direct relation to the specific gravity of liquids and solids, although it does to gases. The explanation is not known, but it appears that the specific heat is influenced by the relative degree of condensation. Boron and carbon, it will be seen by referring to the Table, are about three times as dense as most of the other elements relatively to their atomic weight, and their atomic heats are about three times as small. However this may be, it is known that the specific heat is intimately connected with the chemical nature and constitution of substances, and that when the substances are in the gaseous state, that is, deprived of cohesive force, there is a direct relation between their specific heat, specific gravity, and chemical nature. Thus we found that the unit or combining volume of hydrogen and oxygen respectively weighed 1 and 16. These numbers represent the proportions, but for convenience we will suppose them to be 1 gramme (15·44 grains) and 16 grammes (248 grains). The specific heat of hydrogen is 3·4 (1) according to Regnault, who employed water as his unit; and that of oxygen ·2175 (·625). It will be noticed that when the numbers representing the specific heat and atomic weights are multiplied into each other the result is 3·4 in the case of hydrogen, and in that of oxygen $\cdot 2175 \times 16 = 3 \cdot 4$. The figures representing the specific heats in parentheses afford a rough but ready means of ascertaining the force equivalent to the various specific heats. Thus, in round numbers, a specific heat of 1 according to the hydrogen scale corresponds to an energy of 10 ft.-lbs., so that the

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specific heat of the other substances require to be multiplied by 10 when the energy corresponding to them is wanted. The heat required to heat 1 gramme of oxygen from 0° to 1° would therefore be the quantity corresponding to an energy of 6·25 ft.-lbs. The same numbers may be employed in another way, since, on the assumption that the source of heat is uniform, they indicate the time required to heat the substance through the same number of degrees. The time is inversely as the figures. Thus, if the temperature of oxygen was raised from 10° to 80° in 62 minutes, the same bulk of hydrogen would be heated from 10° to 80° in 100 minutes. In the following table these numbers are given for each element as far as known.

The specific heat of liquid and solid compounds have not been sufficiently studied to enable us to point out the relations between their specific gravity and specific heat; but enough is known to indicate that the specific heat is an important aid in determining the chemical composition. For instance, we frequently have a number of substances possessing analogous formulæ. The group of carbonates already mentioned is one example, and the oxides analogous to silica (SiO_2) form another. In the majority of cases the specific heat numbers of the substance multiplied by those representing the molecular weight give a nearly constant result in each group. A comparison of several minerals analogous to Fe_2O_3 will show what is meant.

Name.	Formula.	Sp heat. Water = 1.	Molecular weight.	Sp. ht. × mol. wt.
Arsenolite . . .	As_2O_3	·12786	198	23·01
Senarmontite . .	Sb_2O_3	·09009	292	26·31
Bismuth ochre .	Bi_2O_3	·06053	468	28·33
Hæmatite . .	Fe_2O_3	·16695	160	26·71
Antimonite . .	Sb_2S_3	·08400	340	28·57
Bismuthite . .	Bi_2S_3	·06002	516	30·97

If the student forms similar tables for himself from the specific heat given under the head of the mineral, he will find a similar result; though there will generally be a considerable range, which is probably due rather to the want

of perfect and comparable experiments than to the want of any relation. The coincidences are so numerous that it is difficult to believe there is not some foundation for the statements made. The compounds formed by the union of single units of monatomic and diatomic elements give a result varying from 11—14, or about 12; the sulphates isomorphous with gypsum, $CaS\,O_4$, about 26; and the carbonates isomorphous with arragonite, $CO_2\,CaO$, about 21.

In the following table the elements are arranged in the order of their atomic weights; that is, the relative weights of their combining units. In the fifth column the numbers relating to hydrogen, oxygen, nitrogen, and chlorine, refer to air = 1.

Name.	Symbol.	Atomic weight.	Sp. gr. H = 1. Water = 11,178.	Sp. gr. Water = 1.	Sp. heat. Water = 1.	Sp. heat. H = 1.	Sp. heat × atomic weight.
Hydrogen ..	H.	1	1	·0629	3·4	1	3·4
Lithium	Li.	7	6 584	·589	·940	·138	6·5
Glucinum ..	Gl.	9	23,473	2·1	·37	·544	3·3
Boron	B.	10·9	29,398	2·63	·25	·037	2·75
Carbon	C.	12	39,346	3·5	·146	·021	1·76
Nitrogen	N.	14	14	·9713	·243	·071	3·4
Oxygen	O.	16	16	1·105	·217	·064	3·4
Fluorine	Fl.	19	Unknown in the free state.				
Sodium	Na.	23	10,851	·97	·293	·043	6·7
Magnesium ..	Mg.	24	19,483	1·743	·249	·036	6·0
Aluminium ..	Al.	27	28,615	2·58	·225	·033	6·0
Silicon.....	Si.	28	..	..	·177	·026	4·97
Phosphorus..	Ph.	31	20,377	1·82	·212	·031	6·57
Yttrium	Y.	?32					
Sulphur	S.	32	22,914	2·05	·202	·030	6·4
Chlorine	Cl.	35·5	35·5	2·47	·121	·035	4·2
Potassium ..	K.	39	9,668	·865	·169	·025	6·6
Calcium	Ca.	40	17,627	1·57			
Cerium	Ce.	46					
Titanium ..	Ti.	50					
Chromium ..	Cr.	52·2	76,345	6·8			
Manganese ..	Mn.	55	89,569	8·01	·121	·018	6·6
Iron	Fe.	56	90,977	8·13	·113	·016	6·3
Cobalt	Co.	58·8	100,003	8·95	·106	·015	6·2

Name.	Symbol.	Atomic weight.	Sp. gr. H = 1; Water = 11,178.	Sp. gr. Water = 1.	Sp. heat. Water = 1.	Sp. heat. H = 1.	Sp. heat × atomic weight.
Nickel	Ni.	58 8	96,801	8·66	·108	·015	6·3
Copper.....	Cu.	63·4	99,931	8·94	·095	·014	6·0
Zinc.....	Zn.	65·2	80,589	7·3	·095	·014	6·2
Arsenic	As.	75	66,620	5·96	·081	·012	6·1
Selenium....	Se.	79	48,065	4·3	·076	·011	6·0
Bromine	Br.	80	33,310	2·98	·084	·012	6·7
Rubidium ..	Rb.	85·4					
Strontium ..	Sr.	87·6					
Zirconium ..	Zr.	89·2					
Molybdenum	Mo.	96	96,130	8·6	·072	·0105	6·9
Columbium..	Cb.	97·6					
Rhodium....	Rh.	104·4	..	..	·058	·0085	6·0
Palladium ..	Pa.	106·6	131,900	11·8	·059	·0086	6·2
Silver	Ag.	108	117,369	10·5	·057	·0083	6·1
Cadmium ..	Cd.	112	99,484	8·9	·056	·0082	6·3
Tin	Sn.	118	..	..	·056	·0082	6·6
Antimony ..	Sb.	120	76,681	6·8	·050	·0073	6·0
Tellurium ..	Te.	125	69,303	6·2	·047	·0069	6·0
Iodine	I.	127	55,331	4·9	·054	·0079	6·8
Cæsium	Cs.	133	21,014	1·88			
Barium	Ba.	137	44,712	4·0			
Vanadium ..	V.	138					
Lanthanum..	La.	139					
Didymium ..	Di.	145					
Tungsten ..	W.	184	196,722	17·6	·033	·0048	6·1
Gold.....	Au.	197	216,406	19·3	·032	·0047	6·3
Platinum....	Pt.	197·4	239,209	21·4	·032	·0047	6·4
Iridium	Ir.	198	236,414	21·1	·032	·0047	6·4
Osmium	Os.	199·2	239,209	21·4	·031	·0045	6·2
Mercury	Hg.	200	151,797	13·5	·031	·0045	6·3
Thallium....	Tl.	204	..	..	·032	·0047	6·6
Lead	Pb.	207	127,876	11·4	·030	·0044	6·3
Bismuth	Bi.	210	109,879	9 8	·030	·0044	6·4
Thorinum ..	Th.	232·4	122,958	11·0	·027	·0039	6·4
Uranium....	U.	240	209,030	18·7	·027	·0039	6·6

This table explains itself; but there are a few discrepancies which require some explanation. The second column on specific heat is calculated from the first; but in the majority of cases they do not appear to correspond. Thus, if 3·4 correspond to 1, then ·940 should correspond to ·276, and so on. The explanation is, that the specific heat of

hydrogen and the gases are referred to air as unity, while the solids are referred to water. A unit of hydrogen is 1 volume, but the molecule of water occupies 2 volumes, and hence the gases are compared with a 1-volume substance, and the solids with a 2-volume compound. In order to have comparable results, all should be referred to one or the other. In the last column all the gases differ widely from the solids on this account. If water be selected as the standard for comparison, they should all be doubled; in which case the result is 6·8; chlorine, however, being an exception. In this last case the anomaly is due to a gas, near its point of condensation into a liquid, being compared with others far above it. In the last column but one the figures are all referred to hydrogen, and hence those relating to solids and liquids are half what they would be if referred to water.

The principal monatomic elements are: —

Hydrogen.	Sodium.
Lithium.	Potassium
Fluorine.	Rubidium.
Bromine.	Cæsium.
Chlorine.	Silver.

The more important in the diatomic group are:—

Oxygen.	Barium.
Sulphur.	Zinc.
Selenium.	Cadmium.
Glucinum.	Mercury.
Magnesium.	Nickel.
Calcium.	Cobalt.
Copper.	Iron.
Strontium.	Manganese.

The triatomic group includes:—

Nitrogen.	Aluminium.
Phosphorus.	Thallium.
Antimony.	Gold.
Bismuth.	

And the following are comprised in the tetratomic group:—

Silicon.	Zirconium.
Carbon.	Platinum.
Tin.	Palladium.
Lead.	Thorinum.
Titanium.	Tantalum.

The most obvious character in minerals is their *crystalline form*, and from its constancy it is a highly important one. The regular figures of rock crystal and the diamond attracted the attention of the ancients, and are mentioned by Pliny, but they were considered, till a much later period, only as curious accidental circumstances. Linnæus was the first who suggested that they must be the result of constant properties, and might be important in the study of minerals; but he appears to have been acquainted with very few, and to have neglected the subject.

Rom de Lisle, a French mineralogist, collected a vast number of crystals of different substances, examined them with care, and, by comparing together those of the same species, found, not only that certain angles were invariable, but that figures the most unlike had a relation to each other; that they were derived from some fundamental form, altered by the solid angles or edges appearing to be removed, and replaced by one or more planes, sometimes small, sometimes so large as to efface those of the original solid, and to produce another.

As an example of this relation, let us compare some of the crystals which are common to Galena (Pl. I.) Fig. 1 is a perfect cube: in Fig. 2 the solid angles appear to be removed, and to be replaced by small triangular planes: in Fig. 3 the triangular planes are increased so as to meet each other: in Fig. 4 they are still larger, and intersect each other. The crystal now assumes the appearance of an octahedron, of which the solid angles are replaced by small square planes. When the triangular faces increase in size, to the exclusion of the square ones, we have a complete and regular octahedron, Fig. 5.

If the *edges*, instead of the angles, of the cube be replaced by planes inclining equally on the adjoining faces, Fig. 8, they will, if increased, produce a dodecahedron with rhombic faces (Fig. 9.) The same form will be obtained if the planes which replace the edges of the octahedron, as in Fig. 10, be enlarged till the original ones disappear. In this figure the solid angles are of two kinds: six, which coincide with those of the inscribed octahedron, are formed by the meeting of *four acute* plane angles; the remaining eight, which agree with the angles of an inscribed cube, are composed of *three obtuse* plane angles.

This connection between solids of very different form will be better understood if the student will take a cubic crystal of fluorspar, and with a knife, properly placed, and a sharp blow from a hammer, detach from each solid angle a small three-sided pyramid. The faces so produced will always be equilateral, and the solid obtained will be similar to Fig. 2 or 3, Pl. I.

If only four alternate angles of the cube be removed (in the direction of the dotted lines, Fig. 1), or, which is the same thing, if four alternate faces of the octahedron be enlarged till the others disappear, he will obtain (Fig. 6, Pl. I.) the regular tetrahedron.

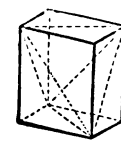

Fig. 1.

The modification represented in Fig. 12, Pl. I., a bevelled cube, if carried to its greatest extent, would produce a solid of 24 faces, which is not uncommon in fluorspar; but it often happens that only *half* of the modifying planes occur, and that they are then placed alternately on the similar edges (as in the last example they were placed on the alternate angles): the cube thus modified would be represented by Fig. 13, Pl. I., and if the bevelling planes were enlarged till they effaced those of the cube, we should have a pentagonal dodecahedron, Fig. 14, Pl. I.

The same planes occur on alternate angles of the octahedron (Fig. 15, Pl. I.), and when they are increased

the two modifications together produce the icosahedron (Fig. 16, Pl. I.), a solid of 20 faces.

The angles of the cube are sometimes replaced by three planes, as in Fig. 17, Pl. I., which, if enlarged, would finally produce a solid with 24 faces, called a *trapezohedron* (Fig. 18, Pl. I.), a form often met with in the garnet. It will easily be seen that the same form is derivable from an octahedron.

In this manner the multitude of crystalline forms at present known, and which amount probably to some thousands, may be referred to a very small number of simple figures, each of which is the *base* or *type* of a group. The first of these groups consists of the solids we have enumerated, which may all be referred either to the cube or the octahedron. There are also many others which may be conceived to arise from the replacement of angles and edges by additional planes, and various combinations of those above mentioned. Crystals of this kind are said to belong to the *monometric* or *regular* system. The distinctive character is this. Suppose the centres of the opposite faces of the cube to be joined by lines or *axes*. These will be three in number, at right angles to one another, and of equal length. All the derivative forms have the same character, provided the point corresponding to the centre of one of the cubic faces is kept uppermost. This in the octahedron is one of the angles.

The simple forms from which those of the second series are derived are the hexagonal prism and the rhombohedron. The latter solid is of two kinds: Fig. 2 represents an obtuse, Fig. 3 an acute rhombohedron. They must not be confounded with the oblique rhombic prisms; for the faces of a rhombohedron are always exactly similar and equal; and it is represented in a symmetrical position when the axis, A X, is vertical; moreover all the modifi-

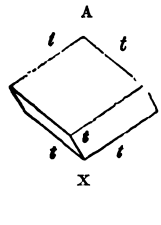

Fig. 2.

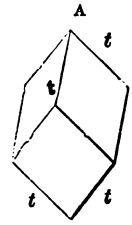

Fig. 3.

cations to which it is liable take place symmetrically with relation to this line, which passes through the *summits* of the rhombohedron. If the student examine a model of this solid, he will see that these summits differ from the other solid angles (which are termed *lateral*), being formed by the meeting of three equal plane angles: in Fig. 2 these are obtuse; in Fig. 3, acute. He will also distinguish the *terminal edges*, *t t t*, which meet at the summits, from the *lateral edges* which meet in the lateral angles.

Equilateral six-sided pyramids and triangular dodecahedrons, of which the edges are alternately equal; twelve-sided prisms, either simple or united with some of these; and rhombohedrons of various angles, also belong to this group. In referring to the rhombohedron it is frequently said to have an angle of a certain size, without indicating which: the angle *t* A *t* is always meant. The replacement of the *terminal edges*, Fig. 4, produces a rhombohedron more obtuse than the primary one, Fig. 5, and the

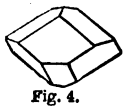
Fig. 4.

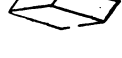
Fig. 5.

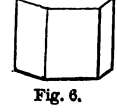
Fig. 6.

Fig. 7.

replacement of the *lateral* edges gives the regular hexagonal prism, Fig. 6; its bases resulting from the replacement of the summits of the rhombohedron, Fig. 7. But if the lateral edges be replaced by *two planes*, this modifi-

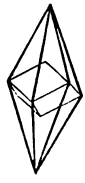
Fig. 8.

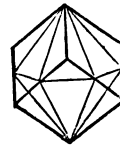
Fig. 9.

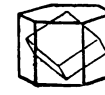
Fig. 10.

cation, if continued so as to destroy the primary faces, would produce a scalene dodecahedron, Fig. 8; that is to say, a dodecahedron, the triangular planes of which

have their sides unequal. The double six-sided pyramid with *equal faces*, Fig. 9, and another hexagonal prism, Fig. 10, arise from the replacement of the *lateral angles* of the primary solid; and it will be seen that the *lateral faces* of this prism correspond in situation with the *edges* of the one above described (Fig. 2). Among the crystals of calcspar the student will find all these modifications of the rhombohedron, and very many others. In this system, which is called the *hexagonal* system, there is a vertical axis and three lateral ones, inclined to one another at an angle of 60°, and to the vertical axis at an angle of 90°. The lateral axes are equal in length.

The square prism (Fig. 19, Pl. I.) is the basis of a very symmetrical group, all the lateral faces being equal, and similarly situated; for it is a general law in crystallization, that whatever secondary planes are found to replace any solid angle or edge of a crystal, every similar angle or edge will be similarly modified. In the cube, therefore, and all the simple solids of that series, every edge and angle undergoes the same alterations. Various octahedrons, both acute and obtuse (Figs. 20, 21), prisms with eight, or twelve, or sixteen sides (Figs. 23, 24), and rhomboidal dodecahedrons, which, though symmetrical, are not regular (Fig. 22), belong to this type (Figs. 19 to 24, Pl. I.).

The forms belonging to this system have a vertical axis, which in prisms unites the summit and the base, and two lateral axes at right angles to each other, and to the principal axis. Two of the axes are always equal in length, and a section, perpendicular to the principal axis, gives rise to squares or figures derivable therefrom. Hence this is called the *quadratic* or *dimetric* system.

The crystals derived from a right prism with a rectangular base, form a series which has less symmetry than those already noticed, because only the opposite faces, two and two, are equal; and the longer and shorter edges exhibit separate and sometimes very different modifications; of these, four and four are equal, and in all respects similarly situated, as shown in Fig. 11. Figs. 12 and 13

show the relation of the right rhombic prism to this parallelopiped: in the first, by removing the lateral edges of the rectangular prism, by planes parallel to its diagonals, we obtain one with a rhombic base: and in the same

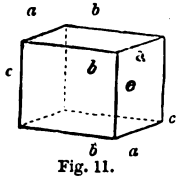

Fig. 11.

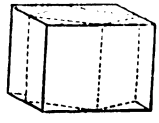
Fig. 12.

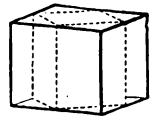
Fig. 13.

manner the rectangular prism may be obtained from the second. Both are primary forms, and from them are derived octahedrons with a rectangular or a rhombic base.

In this system there are three rectangular axes, all of different lengths; hence it is called *trimetric*. A section perpendicular to the vertical or principal axis gives a rhombic figure, or one derivable from it, and hence it is called *rhombic*. The primary form is a rhombic prism, which is frequently described by the angle which the two adjacent faces parallel to the principal axis make with each other. Thus the primary form of witherite is a rhombic prism with an angle of 118° 30′; of alstonite, 118° 50′; of strontianite, 117° 19′; and so on.

In the same manner, from an *oblique* prism with a rectangular base, we derive a rhombic one. The symmetry and equality of the edges and solid angles are indicated by a repetition of the same letters: the secondary

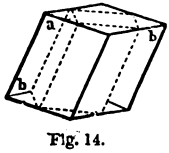

Fig. 14.

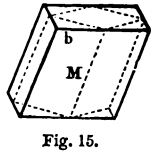

Fig. 15.

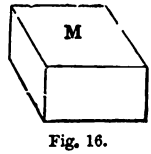

Fig. 16.

forms, which are the consequence of their various modifications, will be noticed in the description of such minerals as have one or other for their primary crystal.

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It should be observed, that if the oblique prism with a rectangular base be placed on one of its lateral faces, it may be considered to be *a right prism*, with a rhomboidal base: by comparing the annexed diagram, Fig. 16, with the former one, Fig. 15, the identity of the two solids will be evident. The crystals belonging to this group form the *monoclinic* system, in which the lateral axes are at right angles to one another, while the vertical axis is oblique to one, and at right angles to the other lateral axis. All the axes are unequal in length.

The last group has for its type a parallelopiped having the least possible symmetry; namely, an oblique prism with an oblique angled parallelogram for its base, Fig. 17. The only equality both of sides and angles, in this solid, is in those which are diagonally opposite. All the axes are unequal, and all are inclined towards one another. Hence the group is called the *triclinic* or *anorthic* system.

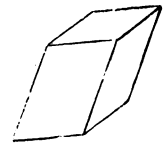

Fig. 17.

The forms belonging to some of these groups are common to several different substances, as for instance, the cubic series, which includes the crystals of the native metals, of galena, spinel ruby, fluorspar, and several others; in the rhombohedral series we find the crystallisations of calcspar, the beryl, phosphate of lime and of lead, red silver ore, &c.

Crystals are found much more commonly in groups than singly, and their modes of arrangement are very various. Cubes are sometimes aggregated so as to form an octahedron, as we see in fluorspar; rhombohedrons are sometimes built up into the form of a triangular dodecahedron, as in calcspar; prismatic crystals are very often united together at one extremity, forming a radiating mass with pointed terminations on the exterior part: this is the case with several kinds of zeolite, amethyst, and many other substances.

But the most singular groups are those called *macles* or *hemitropes*, because they resemble a crystal which has

been cut in two, and of which one part has been turned half round and re-united to the other. Such a division and reunion has, of course, never taken place; a macle consists in reality of two crystals, united by a corresponding face of each, but placed inversely with respect to each other, and which appear to have increased after their union, by a continual addition of particles to each, until the plane of junction is considerably extended. This plane is sometimes parallel to two opposite faces of the primary crystal, as in the example of the regular octahedron: sometimes diagonal, as in the oxide of tin, felspar, and other minerals.

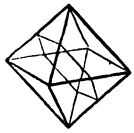

Fig. 18.

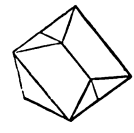

Fig. 19.

In all these numerous forms, we find in the same species the same angles or inclinations of planes, however irregular they may appear from the unequal size of the faces. Distorted crystals of quartz are of very common occurrence,—one face of the pyramid is often much enlarged at the expense of the others; yet the inclinations of the corresponding faces in this and the regular hexagonal pyramids will be found to be the same in both.

In order to ascertain the measure of these angles, and thus establish the identity of a species, an instrument called a Goniometer* is employed. There are several kinds, but that invented by Dr. Wollaston is generally used, being simple in its construction, and easy of application. It consists, Fig. 20, of a graduated circle A B, placed vertically, the axis being hollow, in order to enclose an interior one supporting a movable apparatus C, which is turned by means of the small circle *b*. In order to make use of it, the large circle, which is divided twice into 180 degrees, must be placed at zero (or 180°), and the crystal attached with a little wax to a small plate *a*, so that the edge may be horizontal, and as nearly as possible in a line with the axis of the circle.

Place the instrument on a firm table before an open

* From two Greek words—*gonia*, an angle, and *metreo*, I measure.

window, from which the horizontal lines of some building may be clearly seen, such as the ridge of the roof, the rail of a balcony, &c.; let the plane of the circle be also,

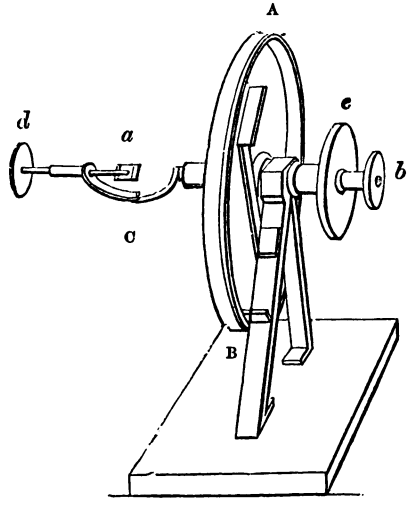

Fig. 20.

as nearly as possible, perpendicular to the plane of the building so viewed.

Placing the eye then very near, and somewhat above the crystal, the inner axis is to be gently turned, until the reflection of one of these lines (the higher ones are generally the best for the purpose) is distinctly seen, by reflection, on the upper face of the crystal; and this movement is to be continued until the reflection appears to coincide with some other horizontal line, seen by direct vision; such as the lower edge of the open window, or the edge of the table. If these two lines correspond exactly, the face of the crystal is placed horizontally; if not, its position must be gently altered by means of the jointed apparatus which supports it, or by turning the circle *d*. The same operation is to be repeated with the

second face; and if its position requires to be corrected, the first face must be re-examined, lest its horizontality should have been deranged.

Supposing the crystal to be now perfectly adjusted, and the reflected line on the first face brought to coincide with a lower one, the great circle must be turned by means of *e* (the crystal being turned by the same motion) until the *same* distant line is reflected in the second face, and brought to correspond with the same lower line.

We shall find the value of the angle sought indicated on the graduated circle, which has turned through the space of the *supplementary angle;* but being graduated in a contrary direction, the true angle is read off.

It will generally be found that the faces of small crystals are more perfectly even than those of large ones; they are therefore, in every respect, better adapted for examination by the reflecting goniometer. But even in those which appear the most perfect, a comparison of the angles of several crystals shows that they sometimes differ *to a very small extent*, in consequence of slight depressions or elevations on their surfaces. But in a great number of substances their natural structure affords us the means of ascertaining the angles of the primary form with the greatest precision.

This structure, which is inherent in their nature, depending on the arrangement of the minute particles of which they consist, becomes perceptible by the manner in which they divide or split when we break them. A slight blow on a piece of calcspar will separate it into fragments which are either rhombohedrons or parallelopipeds, of which the faces meet at the same angles as the planes of the rhombohedron: this solid is therefore, from its symmetry, considered to be the primary form of its crystals.

If the blow be too slight to shatter the specimen, it will often produce internal fissures, which are distinctly seen, in consequence of the light they reflect, to be plane surfaces parallel to the external ones: these are called *planes of cleavage;* and calcspar is capable of this kind of

division in three directions, with equal facility. Sulphate of baryta, also, has three cleavages, which are parallel to the faces of a right rhombic prism. In this case also, the regular solid obtained by cleavage is considered to be the primary form of the species, though in the latter instance, the same crystals might be derived from (or referred to) a right prism with a rectangular base.

It will be evident then, that the observation of crystalline structure, where it exists, is of the greatest importance in mineralogy, not only as showing the relation between forms the most dissimilar, but as affording ready proof of the identity of a species, in circumstances where it would otherwise be extremely difficult to distinguish it; when, for instance, it is disseminated in minute portions through some other mineral: felspar, diallage, and some other substances frequently occur in such a situation.

Some minerals, however, may be cleaved with much greater ease in one or in two directions than in the third. Some readily yield to cleavage in one direction only, as in the case of mica and selenite.

Besides the regular and perfect crystallizations of minerals, of which we have given an outline, the aggregation of crystals, more or less perfect, gives rise to numerous configurations, some of which are peculiar to certain species. In some, the crystals are grouped into spheroidal masses, the edges or points of the crystals appearing on the exterior of the mass, as in blue carbonate of copper, iron pyrites, &c.

The slender prisms in which many substances crystallize are often compressed together lengthwise, and form cylindroidal or bacillar groups; the crystals, even on the exterior, being always deformed and their edges rounded.

The branched and leafy forms and moss-like aggregations, so frequently met with in some of the native metals, consist of more or less perfect crystals. When the crystals are *very* minute and the branches of a more even thickness, they present the form of coral.

The stalactites which so often occur in caverns, irregularly conical or cylindrical in their form, or incrusting

their walls, are produced by the deposition of minute particles, generally calcareous, from water which percolates through their roof or sides. When a small quantity of moisture arrives at the inner surface of the roof, before a drop is formed sufficiently large to fall by its own weight, a portion of it evaporates, and a ring-shaped film of solid matter is left adhering to the rock. Every succeeding drop increases the thickness of this film, until at length a slender tube is formed, which is constantly increased in thickness as well as length. In general the interior is quickly filled up, and becomes perfectly solid; but sometimes the stalactites are hollow throughout a great part of their length. When the water drops more rapidly, a portion of it falls on the floor of the cave, depositing there solid particles, which accumulate and produce masses resembling moss, fungi, and cauliflowers, which are sometimes called stalagmites.

Minerals, also, which do not crystallize, often assume definite forms externally, which are characteristic and deserving of attention. In some the surface consists of portions of spheres of different dimensions: when these are small, somewhat resembling a bunch of grapes closely pressed together, the mass is termed *botryoidal;** when the globular surfaces are of larger dimensions, it is said to be *mammillated:*† chalcedony and malachite are good examples of these forms: and the nodules of iron pyrites, which exhibit a similar surface on a smaller scale, are called *reniform.*‡

We have already remarked that in many substances which crystallize, their regular or laminated structure becomes visible on breaking them; but minerals which do not yield to cleavage in any direction, or with difficulty and uncertainty, break into indeterminate fragments: their form varying with the texture of the mineral. In those which are crystalline and may be termed vitreous, as quartz and beryl, the fracture of the broken part is said to be *conchoidal,* a form which is illustrated in the

* From the Greek word *botrus,* a cluster of grapes.
† Lat. *mamma,* the breast. ‡ Lat. *ren,* a kidney.

fragments of glass; a still better example of the conchoidal fracture is to be found in breaking a large flint pebble; the texture of flint is *compact* and *even*, and all minerals possessing the same kind of structure or texture break in a similar manner.

In others, which are less hard and compact, the fracture will be *uneven* or *earthy*. The native metals, if they do not afford cleavages, have a *hackly* fracture, which may be observed on breaking a piece of thick wire, or plate of metal.

The fibrous structure common to many species, arising from an aggregation of delicate prisms, sometimes parallel, sometimes divergent or radiated, is also evident in the appearance of the fracture. Hence the fresh fracture of a mineral makes us somewhat acquainted with its structure, and should always be remarked.

The first test which is usually applied for the distinction of minerals is their capability of being scratched by other bodies, or in other words, their hardness. For this purpose the mineral is subjected to the action of certain substances which represent a scale of hardness, as indicated in the following list. The degree of hardness is indicated by the mineral standing against each:—

1 Talc (laminated variety).
2 Gypsum (crystallized variety).
3 Calcspar (transparent).
4 Fluor Spar (crystallized).
5 Apatite (transparent).
6 Orthoclase (crystallized).
7 Quartz (transparent).
8 Topaz (transparent).
9 Sapphire (cleavable).
10 Diamond.

In crystals the hardness is not quite the same on all the faces, and may even differ according as the point is drawn in one direction or the opposite. Thus in the case of rhombohedrons of Iceland spar a pin will easily scratch it when drawn in one direction along the oblique diagonal, but scarcely any impression is made when it is drawn in

the opposite direction. For most purposes a rough application of the test is quite sufficient; but there are cases (such as in studying the variations of hardness which the same crystal may undergo), in which a more delicate method of estimating this property is required. In the following descriptions of minerals the hardness given is that obtained by the rough method.

There are other properties which, like the last, depend more or less upon cohesion, such as *tenacity*, *friability*, *flexibility*, *elasticity*, *ductility*, &c. Tenacity is quite distinct from hardness, and is much the same as what is frequently called toughness; it is the power which the particles have of holding together when subjected to a tensile, or stretching strain. Mineralogists usually apply the term to the power of resisting a percussive force, such as the blow of a hammer, &c. When a mineral readily yields to such a force it is *fragile;* when it is easily crumbled down between the fingers it is *friable.* Flexibility is the power of being bent, or having the form altered without breaking, and minerals possessing it may be either elastic, as when they regain their original form, or inelastic when they retain their altered condition—mica is remarkably elastic and flexible, while talc is flexible but not elastic.

The optical properties of minerals afford to the philosopher an exceedingly delicate means of detecting minute differences in the molecular constitution of substances, but, inasmuch as the explanation of the phenomena observed depends upon events, of which it is very difficult to form a clear idea, mention will be made of those only which are most easily understood. It is assumed that light is the result produced by the rapid undulations of an exceedingly rare and perfectly elastic gas-like medium. This medium is called the *ether*, and is supposed to permeate all space not occupied by other matter, including even the intervals between the ultimate molecules of ponderable bodies. The only evidence that there is such a medium is that, assuming it to exist, not only can most of the phenomena of light be fully explained, but the results

that will follow under given conditions may frequently be foretold. Ether, then, may be regarded as matter in its highest state of tenuity, inconceivably light, and inert in all properties but elasticity. In accordance with this, the *particles* of the ether will be alluded to, but the reader must look upon them as being more like the *point* of the mathematician (which has no magnitude but position only) than the actual particles of gross matter. By elasticity is meant the power which a body has of regaining its original bulk when the compressing force is removed. An impulsive force is the same as a compressive force acting for a short time. A compressing force acts directly on a large mass, but an impulsive force acts directly only on a small mass, or on a single particle, if the time during which it acts is sufficiently short. Suppose, then, a medium composed of particles equally distant from one another, and perfectly balanced as regards force, as in Fig. 21. If a forward impulsive force be given to *a* in the first row, it will bound forward and strike against *b* in the second, and impart to *b* nearly all the force it received. The amount which it does not impart depends upon the force required to be overcome in pushing *a* nearer the particles in the second row, and farther from those in the first; in other words, upon the repulsive power or tenuity of the medium. When *a* and *b* are in contact they will exercise a double repulsive force on *o* and *n*, driving them outwards, while *p* and *q* will come nearer together; when *a* recoils, *p* and *q* will be driven outwards. There will result then, first, a series of backward and forward movements in the particles along the line *a*, *b*, *c*, *d*, modified and accompanied by lateral vibrations in the particles of each row. Each row takes up the vibration in succession, and, therefore, a number of rows will be in different states at the same moment, such as may be represented by Fig. 22, which shows a complete vibration to and fro, or a complete wave.

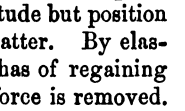

Fig. 21.

When the impulsive force is imparted by rapid instal-

ments the lateral vibrations are quick and the length of the wave is short. On the other hand, the undulations are slower and the waves longer in proportion as the impulsive force is repeated more slowly. In either case the velocity of the wave is the same, provided the medium retains its density unaltered. In the above illustration attention was confined to a single point, and to motion in a single direction; but in light initial force is developed in centres, and the motion spreads in concentric spheres. Hence a line of light spreading outwards from a centre is appropriately called a *ray*. When a ray passes through substances its rate is retarded according as they are more or less dense, that is, its velocity is more or less decreased. This is usually attributed, not to the density of the substances themselves, but to the greater density of the ether, by which they are permeated. When the ray impinges at right angles to the surfaces of a transparent body it does not deviate from its course; but should it impinge on either of them obliquely, it is bent aside or *refracted*. If the substance is physically homogeneous, the refraction is simple, and its amount is proportional to the decrease in the velocity of the light, and is generally indicated by the ratio between the sines of the incident and refracting angles. This ratio, called the *index of refraction*, is generally constant in the same substance at a given temperature, and different in different substances, so that it may frequently be used as a distinguishing character in transparent chemically pure substances. If, however, there is any impurity the ratio is altered, so that it is of comparatively little use to the mineralogist, who has to distinguish between substances which are always more or less impure. All bodies which are amorphous or which form crystals belonging to the regular system are singly refracting.

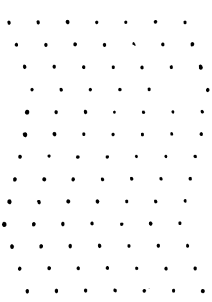

Fig. 22.

When the ray of light passes through substances which are not physically homogeneous, it undergoes modifications in direction depending upon the structure. Thus in all crystals not belonging to the regular system the ray is divided into two, of which one is called the *ordinary* and the other the *extraordinary*. Hence it is that when objects are looked at through such crystals, transparent calcspar for instance, they appear to be doubled. The rays traverse the crystal in different directions and at different rates. In most such crystals, however, there is one or a few directions in which the light may pass through without being split up, or *doubly refracted*. These directions or planes are called *optic axes*, the number of which has a close connection with the crystalline form of the mineral.

Thus there is one direction in which a line (or any other object) may be viewed through calcspar, without appearing double; this is in the direction of the axis of the rhombohedron. If the two summits of a rhombohedron, or the bases of an hexagonal prism be polished, on placing it over a dot, and the eye immediately above it, we shall see but one image of it.

In the crystals also, which are referable to a square prism, no double refraction is perceptible in the direction of their axis: in both cases it is called the *axis of double refraction*.

In crystals where this kind of symmetry does not exist, as when they are derived from prisms that are oblique, or have not a square base, there are *two* axes of double refraction, or two directions only, in which a single image will be perceived.

The property of double refraction may therefore be valuable in assisting us to distinguish minerals, which at first sight appear to resemble each other, if, being cut and polished, or in irregular fragments, we have no indication of their external form. A fragment of red topaz, for instance, will refract doubly: one of spinel ruby, the crystals being octahedral, will not.

But as the amount of double refraction is, in most

substances, very small compared with that of calcspar, it is seldom possible to discover, by merely looking through them at a line or dot, whether they really possess this property; besides the difficulty there may be of obtaining transparent fragments of sufficient size to be cut in different directions. A simple experiment, however, with polarized light, will determine the point.

Light may be polarized by several different methods; as, by reflection at a certain angle, from a polished surface; by transmission through plates of tourmaline, &c. For the mineralogist, two thin plates of this substance, cut parallel to the axis of the crystal, afford the most convenient apparatus. They are to be fixed, each in the aperture of a short tube of wood or brass, of such dimensions that one shall be capable of turning within the other. On looking through the two plates, placed with their axes *parallel*, we shall see, as in any similar case, the brown or green colour of the tourmaline; but if one of them be turned, so that its axis shall be at *right angles* to that of the other (their planes being still parallel), the light will be wholly, or almost entirely, intercepted. On introducing between them a fragment or plate of the mineral under investigation, if it do not possess the property of double refraction, no change will take place; but if it refract doubly, light will be visible, and in a very singular manner: a number of concentric coloured rings will be seen, intersected by a black cross. On turning either plate of tourmaline one quadrant of the circle, the appearance will still be the same; as also when it has described half or three quarters of a revolution: but at all the four intermediate points, a white cross will take the place of the black one, and the coloured rings will occupy the dark spaces that intervened between those of the former set, Figs. 23 and 24.

If the mineral have but one axis of double refraction, and the plate be cut perpendicularly to it, the rings will be circular; if obliquely, they will be elliptic.

But if the crystal belong to any of those series which indicate *two* axes of double refraction, there will be two

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adjoining systems of coloured rings, traversed by a black cross, Fig. 25; and on turning one of the plates of tourmaline so as to produce the complementary system of

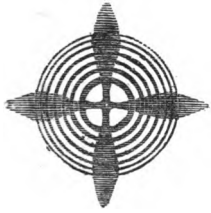

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

rings, they will have the appearance represented in Fig. 26. Many other phenomena presented by minerals, when viewed with polarized light, are extremely curious and beautiful, but they are far too numerous to be detailed here.

The character of transparency exists in various degrees in minerals: some are perfectly *transparent* (and when colourless also, are said to be *limpid*); others, which allow objects to be indistinctly seen through them, are *semi-transparent:* when they transmit only a little light they are said to be *translucent.* Some are translucent only on the thin edges of fragments; others are quite opaque. But it should be observed whether opacity is really a character of the species, or whether it is caused by the intermixture of some foreign matter. Opacity is sometimes also the consequence of decomposition, loss of water, &c.

With regard to the brilliancy of minerals, there are several kinds of lustre which are very distinct from each other: for instance, some have a *metallic* lustre, others a *vitreous* or *glassy* lustre; others, again, either from the nature of their texture or structure, exhibit an *adamantine, oily, resinous, waxy, pearly,* or *silky* lustre.*

* The *pearly* lustre which is often to be observed on the bases of prismatic crystals, appears to be the result of a laminated structure; and the silky lustre, of a fibrous structure.

Many substances, being of an earthy texture, are without lustre, or quite *dull;* in others, according to their degree of compactness, we find several degrees and varieties of lustre in various parts of the same mass. There is also a kind of lustre peculiar to some minerals, denominated *semi-metallic;* it is very commonly found in mica, as well as in some metallic ores.

The *degrees* of lustre should also be remarked; the highest degree, *splendent*, is applied almost exclusively to the diamond and white carbonate of lead, which from their very high refractive power have a greater brilliancy than any other substance.

Many crystals are *brilliant;* others are *shining, glistening,* or *glimmering:* and these terms apply also to the appearance of the fracture, which should always be observed when recently made, and before it loses the form and lustre that are peculiar to it. Some minerals which are soft, and have little or no lustre, become shining when scratched by a sharp point.

The colours of minerals are either essential to them, as in the sulphides, oxides, and acidiferous compounds of most metals, and in those species of which they are essential constituents; or they are the effect of a casual intermixture of these substances in species which, when pure, are naturally colourless. Of the latter sort are the colours of felspar, calcspar, rock salt, marble, and jasper, in which the various tints of red and yellow are generally due to the oxide and hydrous-oxide of iron. Other minerals derive a brilliant green colour, some from carbonate of copper, others from the oxide of nickel or of chrome. In species of which the colour is a permanent character, its intensity is often so far varied by a difference of texture or a confused crystallization, that red, brown, and green substances appear, in a mass, to be black; but on being pulverised, their true colour will be seen; it is therefore advisable, in describing a mineral, to state what its colour is when reduced to powder.

The intermixtures of colouring matter, which are merely mechanical, render a mineral more or less opaque;

thus, the red and yellow jasper, already mentioned, are chalcedony (which when pure is highly translucent, or even semi-transparent), coloured by minute particles of oxide of iron, which are themselves opaque. But colours, which, though they may not be essential to a species, are the result of *chemical combination*, do not impair its transparency: such is the violet tint of amethyst, which is derived from a minute portion of the oxide of manganese combined with the quartz; and the green of the emerald, which may in some cases be due to oxide of chrome.

In consequence of the variable quantity of colouring matter, whether chemically combined or otherwise, many substances present various tints and shades of colour; so that we particularise them as *blood-red, flesh-red, chestnut-brown, lemon-yellow, sky-blue*, &c.

Accidental colours, being unequally distributed, often produce parallel bands, either straight or curved, and clouded forms, as in agates: sometimes the colour takes the form of leaves and moss, or runs through the mass in veins, as in marble.

There are still other colours, which are neither essential to minerals, nor yet produced by intermixture. Some, as the sulphide of antimony, exhibit a brilliant superficial tarnish, in which the prismatic colours are regularly arranged. In transparent substances, prismatic colours are perceived in the interior, and arise from minute cracks or fissures containing films or particles of air: these are often movable by a slight pressure.

A very curious peculiarity of colour called *polychroism** is connected with the phenomenon of double refraction. Some minerals, placed between the eye and the light, transmit different colours in different directions: tourmalines, viewed parallel to their axis, are generally opaque · perpendicularly to it, they appear to be green, red, brown, &c. This difference is not observable in *all* doubly refracting substances; but in some which have two axes of double refraction three different tints have been ob-

* From two Greek words—*polus*, many, and *chroa*, colour.

served. Minerals crystallising in the cubic system never transmit more than one colour, if their composition and texture be homogeneous throughout.

In some minerals, a peculiar light is produced either by friction or by heating them, which is called *phosphorescence*. On rubbing together two fragments or pebbles of quartz, a faint greenish light will be perceived: the same effect can be produced with certain marbles. Other substances, when placed on a heated shovel, emit a brilliant phosphorescence, which in some is green; in others, pale violet. The best mode of conducting this experiment, if the specimen is powdered, or in small fragments, is to strew it on a shovel heated nearly to redness: but if it be an inch or two in length, it is better to heat it slowly, and not beyond the necessary degree; by which means the operation may be frequently repeated without injuring it.

The property of *taste* is confined to soluble minerals, of which some are *astringent*, as the sulphate of iron; a few *alkaline*, as carbonate of soda; others, *bitter*, as Epsom salt; or *sour*, as the sulphuric acid which occurs among recent volcanic products: a few as sal ammoniac, are pungent.

There are very few minerals which exhale any *odour*, unless by the application of heat or moisture. The bituminous odour is generally perceptible in the varieties of bitumen, and the inflammable substances which contain it; and this becomes stronger when they are heated. The powerful smell of sulphurous acid, which is known to most persons, is immediately perceived when sulphur and its compounds are exposed to heat; and by the same means the odour of arsenic becomes evident: it has a great resemblance to that of garlic. Friction is in many cases sufficient to produce this effect, as in certain bituminous limestones.

On the other hand, many substances when breathed on, or otherwise exposed to a slight degree of moisture, give off an odour which, from being strongly perceptible in all kinds of clay, is called the argillaceous odour.

All minerals are more or less susceptible of becoming *electric*, either by *friction*, by *pressure*, or by *heat*; in some, this property may be excited by all these methods. A topaz, a tourmaline, and a number of other minerals, when rubbed on a piece of woollen cloth, will, like a stick of sealing-wax or glass rod (so excited), attract small light bits of cotton or thin paper. But the metals, and those ores which approach to a metallic state, being conductors of electricity, this result cannot be obtained unless they are previously insulated, by placing them on a support of glass, or some other non-conducting substance. A very small piece of gilt paper attached by a silk thread to a bent glass rod forms a simple apparatus which will exhibit the electricity a mineral has thus acquired: on approaching it to the gilt paper it will immediately affect it. The specimen, also, should be suspended by a silk thread, or held in a pair of pincers * having a glass handle.

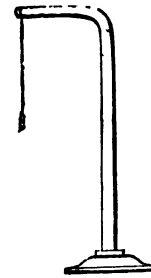

Fig. 27.

The substances which become electric by heat, such as tourmaline and topaz, usually exhibit *electric poles:* that is to say, one end of the crystal becomes positively, the other negatively, electric. This may be ascertained by previously communicating to the gilt paper either kind of electricity. For instance, when the crystal is heated, let the gilt paper be touched by a stick of sealing-wax that has been well rubbed: if the crystal, on approaching the apparatus, repels the paper, that end is also *negatively electric*, and it will be found that the other end attracts it, and is therefore *positively electric*. The crystals which acquire electric poles by heat have another peculiarity: namely, that their opposite extremities are differently modified: tourmalines are sometimes termi-

* The latter plan is objectionable if we wish to ascertain whether the substance is capable of becoming electric by simple exposure to heat, because many which are not so become electric by pressure.

nated at one end by three, at the other by six or nine planes. This is yet more striking in the substances whose crystals are cubes modified on the alternate solid angles.

However curious we may consider the electric phenomena of minerals, they appear to be manifested with too much uncertainty to form a distinguishing character. Different crystals of the same substance will acquire, some negative, others positive electricity, according as they are transparent or otherwise; in general, transparent crystals with bright polished faces become positively electric, and such as are not limpid, or have a rough exterior, become negatively electric.

The only mineral which is capable of becoming a magnet, or loadstone, is *magnetite:* this mineral alone exhibits the magnetic poles; but many iron ores, and even many other substances which contain a large proportion of iron, not too highly oxidised, will attract the magnetic needle perceptibly. The metals *cobalt* and *nickel* likewise possess this property, but less powerfully.

With regard to the *chemical examination* of minerals, there are two modes of operation, called the *moist* and the *dry:* in the former they are dissolved either in water, or, if that is not possible, in some acid; in the latter they are exposed to great heat by means of a *blowpipe.* For the mineralogist this mode of operation is by far the most convenient, both because the results are quickly obtained, and because very little apparatus is necessary: he requires, for his furnace only a lamp or candle, some strips of platinum foil, and a pair of pincers with tips of the same metal, for supporting the specimens to be assayed; or, in some cases, a piece of well-burnt and solid charcoal; and a few small bottles containing fluxes.

The blowpipe, in its simplest form, is a bent tube, nine or ten inches long; at one extremity tapering to a fine point. It is used to direct and concentrate a flame, by supplying to it a constant stream of air in one direction, the small end being placed just within the flame,

and the air being furnished by the operator blowing through it.

Some difficulty may be experienced, at first, in producing an equal and uninterrupted stream of air and a steady flame: it can only be effected by supplying the air, not immediately from the lungs, but from the mouth, *as from a reservoir*, which must not be allowed to become exhausted; otherwise, the experiment will be incessantly impeded by the necessary act of respiration.

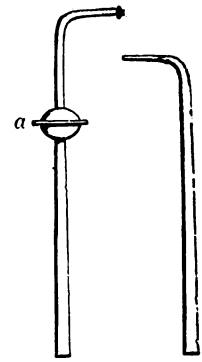

Fig. 28

Some blowpipes have a cylindrical or globular cavity, in which the moisture of the breath is condensed and retained;* it might otherwise be carried by the draught into the flame, and would interfere with the experiment.

A silver tube is the best, as not liable to corrosion; brass communicates an unpleasant smell to the fingers; but a cheaper instrument may be made of tinned iron, the cavity being square and placed at the bend. In all cases, however, the tip should be of platinum and removable, that it may be cleansed if necessary, in acid, or by heating it to redness.

A small lamp, fed either with oil or melted tallow, will furnish a good flame for the exercise of the blowpipe; but a candle with a large wick may be used, and, in travelling, is perhaps the most convenient.

When the student can produce a steady flame with this instrument, he will find that it consists of a cone of yellow light, enclosing a blue one. The heat is most intense at the extremity of the blue flame; this is called the *reducing flame*, because it de-oxidises, wholly or in part, the substances that are exposed to it, and it is capable of melting a great number that are not fusible in the outer one. The latter is called the *oxidising flame*, because, as it does not

* This cavity is made in two parts and unscrews at *a*.

entirely prevent the contact of the air, it permits the subject of experiment to become oxidised.

In the inner flame, some of the metallic oxides are reduced to the metallic state; and their reduction is assisted by placing them on a piece of charcoal as a support, because it absorbs the oxygen from them when heated. For this purpose, a small hollow must be scraped in the charcoal, and the mineral (previously crushed or powdered) fixed in it with a little wax or tallow, which will prevent it from being displaced on exposure to the draught of air, and will itself quickly burn away.

A quantity, varying from the size of a mustard seed to that of a peppercorn, is ample for most experiments. Sulphides, when heated, give off the odour of sulphurous acid, and after some time they are generally reduced to the metallic state. When arsenic is combined with them, the smell of garlic will be perceived; and the few which contain *selenium* afford a pungent odour like that of horseradish.

Some minerals, both earthy and metallic, are fusible by the blowpipe without addition: but many others cannot be melted unless mixed with some alkaline or saline substance, with which they fuse into a glass, more or less transparent, or a kind of enamel: these salts are called *fluxes:* carbonate of soda, borax, and salt of phosphorus, are most commonly used, and they may generally be placed with the subject under examination on a slip of platinum foil. In some cases, the glass produced by fusion is colourless, containing small globules of the reduced metal; in others, it receives from the metal a colour which is peculiar to it: thus, the ores of cobalt melted with borax (or common glass) will always produce a fine clear blue colour; those of manganese, a rich purple like that of the amethyst. It must be remarked, however, that the same metallic oxide will produce different colours with different fluxes, or in the two flames; and therefore, if the result of one experiment should not be satisfactory, it may often be verified by a second. The annexed table, showing the results obtained by subjecting several oxides to the action

of the blowpipe, with different fluxes, will be found useful for reference. (See p. 60.)

When a mineral is heated in a closed glass tube, by directing the flame against and beneath it, if it contain water, it will be volatilized, and condensed on the upper surface. If *fluorine* be one of the components, the glass may be corroded by it: but this gas is not always disengaged without fusion with salt of phosphorus.

As it is not possible in this introduction to detail most of the experiments for examining minerals by *solution*, we will observe, First, that effervescence on the application of an acid generally indicates *a carbonate:* in all carbonates of lime the effervescence is very brisk, but in some other species it is scarcely perceptible without the assistance of heat. Secondly, that some minerals that do not effervesce, when dissolved in acids, are converted into a *gelatinous* substance; this is the case particularly with some siliceous minerals that contain a portion of alkali: heat is often necessary to accomplish this change, and the acid employed should be strong; but to produce effervescence, the acid should be diluted with water.

The issue of a new edition of this volume affords an opportunity of adding a few remarks.

The specific gravity of minerals is still usually obtained by means of weighings in water and in air, but this method is often impracticable or tedious when different mineral species are intimately intermixed in small pieces or grains. In these cases the use of fluids of high specific gravity has been extensively adopted. These can be regulated to considerable nicety, and the most finely powdered minerals can be sorted off, according to their specific gravities, with great accuracy. As yet the fluids employed are of such a character that they can only be safely or conveniently used in chemical laboratories. The most generally known is Sonnstadt's solution, which consists of iodide of mercury dissolved in a solution of iodide of potassium. It can be made of all specific gravities from 3 or thereabouts and under by diluting

it with water. On board ships, and in places where delicate balances cannot be used, this method is very useful.

Optical research has been developed to a high degree, and much new light has thereby been thrown on the minute crystalline structure of minerals. Thus many minerals present what appear to be optical properties of an anomalous character. Such anomalies are ascribed by some to isometric crystals being built up by the symmetrical twining or grouping of crystals which are themselves not isometric; to the crystals belonging in appearance to one system being compounded of smaller crystals belonging to another system; or to internal tension of crystals whereby the rays of light are caused to take a somewhat different path than they would do in crystals of uniform tension throughout. None of these views apply to all cases; but each is true in some cases. The last supposition, however, seems to have most evidence in its favour, and is strongly supported by the fact that when gelatine is cast in moulds under pressure, it acts in the same way on light as certain minerals do; as for instance, analcime, boracite, and many others. Klein shows that in boracite the outer part of pure crystals is different optically from the inner in such a way that unequal tension is the most satisfactory explanation that has as yet been proposed.

The index of refraction is so distinctive a feature of minerals, that even a hundred years ago a French writer suggested it as a means of recognising minerals; but his suggestions bore no fruit, owing to the want of a method for practically applying it with accuracy and convenience. This defect has now been supplied by the simple apparatus devised by Mr. Sorby, and which can be adapted to any ordinary microscope. By this apparatus the refractive qualities of any transparent mineral can be readily distinguished and accurately measured even when the fragments are small and imbedded in other minerals in the midst of a rock. Thus, in the case of minerals with one or more axes of

refraction, the measurement of the index of refraction is obtained by the varying focal length between the object glass and the surface of the mineral. This length is increased in proportion to the greater refractive power of the substance under examination. In doubly refracting substances, the ordinary and extraordinary rays behave differently, producing images of differing shapes, visible only when the light traverses the substances in definite directions, and are seen at different focal distances. Special physical peculiarities are thus made manifest, whereby the smallest fragment of many minerals can be identified. There appears to be so close a connection between the refractive indices and the chemical composition of minerals, that these characters promise to be of high importance in mineralogy, and to be valuable adjuncts to the data obtained by the help of the polariscope and polarized light.

Colonel Ross has introduced many improvements and new processes in blowpipe manipulation. Thus, his aluminium plate is a useful substitute for charcoal as a support. It costs little, lasts long, is clean and portable; while owing to its withdrawing the heat away from the assay and retaining its whiteness, the character of the sublimates is more easily distinguished in many cases, and in some a sublimate is evident, although on charcoal none can be seen.

The analysis and testing of minerals in the wet way in solutions has generally been conducted with the stronger mineral acids. Owing to their corrosive character and liquid form, much inconvenience attends their use, and the difficulties attending their transportation for use in the field or in journeys has prevented their employment, and compelled the observer to have recourse to the blowpipe. It is found that the commoner organic acids, such as acetic, oxalic, tartaric, and citric acids, will serve almost as well as the mineral acids, and Professor Bolton has worked out a systematic method of investigation which can be easily

applied. As citric acid has the strongest action he relies chiefly on the use of it alone. The solid acid is dissolved in cold water until a saturated solution is produced. The minerals are pulverized, freed from impurities, and treated with the reagents both hot and cold in test-tubes. As nitrate of potassium, iodide of potassium, and fluoride of ammonium are decomposed by citric acid, liberating nitric acid, hydriodic acid, and hydrofluoric acids, these acids can be brought into play to decompose those minerals which citric acid alone will not act upon. The test with hydrofluoric acid is not suitable for field work, since tests with it should be made in platinum vessels.

The carbonates effervesce readily with the organic acids. In some cases citric acid is not the best to use. Thus oxalic acid forms characteristic compounds with the bases. Calcareous spar is decomposed by it, and an amorphous precipitate of powdery oxalate of lime is formed; with witherite beautifully feathered crystals of oxalate of baryta appear; siderite yields a pale yellow granular protoxalate of iron; and cerussite a precipitate of oxalate of lead.

The following lists, derived from the table, given by Professor Bolton, will show the most marked characteristics of the action of citric acid on minerals, according to different conditions. The cold saturated solution of citric acid will decompose the following without evolution of gas:—Clausthalite, leucopyrite, atacamite, brucite, pyromorphite, mimetite, triphylite, triplite, vivianite, libethenite, olivenite, pseudomalachite, wavellite, pharmacosiderite, torbennite, autunite, cryptomorphite, anglesite, and brochantite. On boiling, the following are also decomposed without any gas being evolved, viz., cuprite, zincite, malaconite, goethite, limonite, allanite, apatite, wolframite, wulfenite, crocoisite, and gypsum.

Minerals decomposed by the cold solution, with liberation of carbonic acid gas:—Calcite, dolomite, gurhoffite, ankerite, rhodochrosite, smithsonite, arrago-

nite, witherite, strontianite, barytocalcite, cerussite, malachite, and azurite.

On boiling the following are acted on in the same way, but in several cases the carbonic acid is from the citric acid:—Hausmannite, pyrolusite, manganite, psilomelane, wad, magnesite, and siderite.

Minerals decomposed by the citric acid solution, with evolution of sulphuretted hydrogen, when cold or on boiling:—cold: Stibnite, galena, alabandite, sphalerite, pyrrhotin; on boiling: Bornite, jamesonite, bournonite, boulangerite, and kermesite.

The cold solution decomposes the following, with separation of silica:—Wollastonite, rhodonite, chrysolite, willemite, nepheline, lapis lazuli, chondrodite, pectolite, laumontite, chrysocolla, calamine, apophyllite, thomsonite, natrolite, mesolite, analcime, chabazite, herschelite, stilbite, and deweylite; while the boiling solution acts on these, as also on tephroite, ilvaite, phlogopite, datholite, prehnite, heulandite, serpentine, chrysolite, bastite, and gieseckite.

When nitrate of soda is added to the boiling solution, the following are dissolved:—Silver, mercury, copper, arsenic, antimony, bismuth, sulphur, bismuthite, domeykite, argentite, hessite, tiemannite, millerite, niccolite, iron pyrites, chalcopyrite, linnæite, smaltite, cobaltite, ullmannite, marcasite, arsenopyrite, nagyagite, covelline, berthierite, pyrargyrite, tetrahedrite, tennantite, stephanite, polybasite, enargite, uranite, and hübnerite.

The addition of iodide of potassium to the boiling solution dissolves nearly all those already mentioned and also the following, viz.:—Realgar, orpiment, cinnabar, hæmatite, menaccanite, washingtonite, magnetite, franklinite, braunite, enstatite, augite, spodumene, hornblende, actinolite, pargasite, olivine, almandite, pyrope, colophonite, and epidote.

The following list includes those minerals which were examined but were not decomposed by the reagents mentioned in this tabular list:—Graphite, molybdenite,

proustite, fluor spar, cryolite, corundum, spinel, chromite, chrysoberyl, cassiterite, rutile, quartz, hyalite, diopside, petalite, asbestos, beryl, zircon, vesuvianite, zoisite, dichroite, biotite, muscovite, lepidolite, wernerite, leucite, anorthite, labradorite, oligoclase, albite, orthoclase, tourmaline, andalusite, fibrolite, kyanite, topaz, titanite, staurolite, talc, kaolin, ripidolite, columbite, samarskite, scheelite, barytes, celestine, and anhydrite.

Szabo's method of determining felspars admits of a wider application, but in every case minute observation and great care in securing uniformity of condition are requisite. His method is based on the fusibility of the felspars, and on the colouration they impart to a flame. The flame employed is that of a Bunsen burner in a lamp of a particular pattern. The flame is marked off into three regions: first, the base; second, that which is about one-fifth of an inch above the base; and a third formed about one-fifth of an inch above the chimney after it has been put on the lamp, the temperature of which is estimated to be about 4172° Fahr. A thin platinum wire is used, of the same diameter in every experiment; and the piece of felspar tested must be as nearly as possible the same size, or about that of a mustard-seed. The platinum wire is fixed into glass holders. The felspar is then placed in the different parts of the flame, being held in each for a fixed time, or one minute. If it fuses before, or gives rise to any phenomena, the time at which such occur is taken in seconds. There are many advantages in this method for beginners, since with the blowpipe much depends upon manipulative skill, and the results are often too rapid. The felspars are characterized by alkaline bases, and the varying proportions of these influence the fusibility and the colouring of the flame. All contain some sodium, as all colour the flame yellow. Sodium has a most intense colouring power, and overpowers the colours produced by the other bases. The size or depth of the yellow colouration depends upon the percentage

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of soda present; and by this character alone it is possible to state roughly how much soda is present, from less than 1 per cent. to 16 per cent. All the soda and lime felspars contain less than 4 per cent. of potash, while, as a rule, red colouration only appears when there is more than 4 per cent. of potash. Hence, if a felspar shows indications of a small amount of soda, accompanied by a visible red colour, then it is manifestly one of the potash felspars. The percentage is here also indicated by the degree of visibility. If a little gypsum be added to the felspar, then the red colouration appears with amounts of less than 1 per cent. The colouration of the flame by the potassium is observed by looking at it through a deep blue cobalt glass, or through a solution of indigo in strong sulphuric acid. The presence of the lime is indicated by the increasing difficulty of fusibility, and by the visibility of the calcium line when the felspar has been dipped in hydrochloric acid and then placed in the lower part of the flame, which must then be looked at through the spectroscope.

A large proportion of those parts of this chapter which relate to the crystalline forms, the optical and electrical properties, the colour, lustre, and blowpipe reactions of minerals, is taken, with various alterations, from Dana's "Rudimentary Treatise on Mineralogy," which originally formed No. 4 of the Weale Series.

OXIDES OF	FUSED WITH BORAX.		FUSED WITH SALT OF PHOSPHORUS.	
	OXIDATING FLAME.	REDUCING FLAME.	OXIDATING FLAME.	REDUCING FLAME.
Tellurium	colourless	grey and opaque, containing minute globules of metal	colourless	grey and opaque
Titanium	colourless, or opaque white	yellow, amethyst, or blue, according to the quantity of oxide	colourless	yellow; on cooling, a bright violet
Bismuth	colourless	grey in cooling, colourless when cold	yellowish brown, colourless on cooling	grey and opaque when cold
Chrome	emerald green, brightest cold	brown, hot; pale green, cold	deep green	pale green
Copper	bright green, hot; blue, cold	colourless, hot; opaque and deep red when cold	green	dark red when cold
Uranium	dull yellow	dull dark green, approaching black	straw yellow, cold	green, most intense when cold
Lead	colourless, cold	partly reduced	colourless	enamel, white or yellow
Cerium	orange or red, hot; yellowish, cold	colourless	red, hot; colourless, cold	colourless
Iron	red, hot; yellowish or colourless, cold	bottle green or bluish green	same as with borax	
Manganese	amethyst	colourless, if cooled quickly	amethyst	colourless
Cobalt	blue	blue	blue	blue

CHAPTER II.

GASES AND WATER.

Section I.—Simple Gases.

Hydrogen. (H. Atomic weight, 1.)

This gas rarely occurs free in nature; it is emitted from crevices during earthquakes, and from volcanoes when in eruption. It is an essential ingredient of all hydrates, hydrous acids, and hydrocarbons. It is most abundant in marsh gas (H_4C). It is colourless, tasteless, transparent, inodorous. It will combine with oxygen at ordinary temperatures under the influence of certain minerals, such as platinum, osmium, iridium, palladium, gold, and silver; with chlorine, under the influence of daylight, sunlight, the electric, and the lime-light, or at a temperature above 369° F. At a red heat it combines with the vapour of bromine and iodine. It is not known to combine directly with any other element. It is the lightest body in nature, the specific gravity being ·0692 (1) as compared with air = 1. It is sparingly soluble in water, 100 cubic inches of which absorbs 1½ cubic inches of the gas at about 60° F. It possesses neither acid nor alkaline properties, and is powerfully electro-positive. Its index of refraction is 1·000138, and its specific heat, as compared with an equal weight of water, is 3·4090 (1). Some further remarks on hydrogen will be found in Chapter I. In the descriptions of minerals the specific gravity, the specific heat, the index of refraction, and other properties, are expressed in numbers, according to the usual standard, but in most cases the same properties are expressed in numbers referred to hydrogen as unity. These last are always placed in parentheses. The unit for refraction is ·000138, or the difference between hydrogen and vacuum.

Oxygen. (O. Atomic weight, 16.)

It resembles hydrogen in many of its properties, but differs from it remarkably in others. It is the most abundant of all elements, forming $\frac{8}{9}$ of water, nearly $\frac{1}{4}$ of the atmosphere, and about $\frac{1}{2}$ of silica, chalk, and alumina; these substances are so widely distributed that nearly all the more important rocks and minerals contain more or less oxygen; indeed, the outer few miles of the earth's crust is almost entirely composed of oxides and oxygenated substances. Oxygen is colourless, tasteless, inodorous, and is slightly soluble in water, being dissolved to the extent of about 3 per cent. by volume at ordinary atmospheric temperatures. Its index of refraction is 1·000272 (1·97); sp. gr., 1·1056 (16); and specific heat for equal weights, ·2175 (·0625). It is the most magnetic of all gases, and is more so than the chloride of iron, which is the most magnetic of all liquids; as compared with iron = 1,000,000, its power, weight for weight, may be represented by 377. Oxygen combines with nearly all the known elements either by direct union or by indirect chemical action. Fluorine is probably the only exception. Direct combination takes place with but few bodies at ordinary temperatures when the oxygen is dry, but when moist it acts on most metals, which become slowly converted into oxides. The metals will combine directly with oxygen on raising the temperature, or reducing them to powder. The most remarkable property of oxygen is its powerful combustibility.

The chemical activity of oxygen appears to be connected with its relative state of condensation. Thus, when oxygen is condensed by platinum black its properties approach those of *ozone*. This substance has a specific gravity of 1·658 (24), and a peculiar odour. Its properties resemble those of ordinary oxygen, but are marked by greater intensity; so that what oxygen effects at high temperatures, ozone will accomplish at ordinary temperatures, and dry ozone will do that which it will require moist oxygen to perform under the same circum-

stances. The main differences between the two gases appear to be due to differences in density, but why the one should be relatively heavier than the other under the same conditions is a question that remains to be solved.

Nitrogen. (N. Atomic weight, 14.)

It occurs free in the atmosphere, of which it forms four-fifths, in certain cavities in fishes and other animals, as also in plants. Many springs yield it in considerable quantities, through the waters of which it may incessantly bubble. There are many examples of this in North America, and the tepid springs at Bath are good English examples. One of the Bath springs is said to yield nearly 270 cubic inches of this gas every minute. This phenomenon is not peculiar to America and England, for there is reason to believe all, or nearly all, warm springs evolve more or less free nitrogen. Volcanoes also yield immense quantities of this gas. This evolution of nitrogen appears to be associated in some way with the deoxidation of the air, which finds its way into the cavities of the earth's crust. Nitrogen is colourless, transparent, inodorous, insipid. Its specific gravity is 0·9713 (14); refractive index, ·000300 (2·169); and specific heat (Regnault), ·2438 (·0757). It is sparingly soluble in water, which absorbs $1\frac{1}{2}$ per cent. by volume at 60° F. It will not combine with oxygen, hydrogen, or carbon at ordinary, but does so at elevated, temperatures. Its chemical affinities are weak, but it enters into the composition of numerous compounds, more especially such as are connected with the nutrition of plants and animals. Its weak affinity gives rise to the tendency which nitrogenous compounds possess of being easily decomposed. In one class of compounds it combines in the proportion of 1 volume to 3, as in ammonia (H_3N) and the nitrites; while in another class the volume proportion is as 1 to 5, as in most of the nitrates. These volume proportions apply only to monatomic elements, but they will also apply to other elements if the 1 be replaced by the figure representing their degree of atomicity.

Chlorine. (Cl. Atomic weight = 35·5.)

Chlorine does not occur in the free state, but is widely distributed in combination with other elements, forming part of the chlorides of magnesium, sodium, calcium, and potassium, all ingredients of sea water; and of the chlorides of lead, mercury, and silver. It forms rather more than 97 per cent. by weight of the hydrochloric acid ejected from volcanoes. It has a yellowish green colour, a pungent irritating odour, and an astringent taste. Its sp. gr. is 2·47 (35·5), and its sp. ht., ·1210 (·0355). Its refractive power is less than that of water. It is unaffected by light, heat, or electricity; but, when moist, light causes it to decompose water, and to combine with the hydrogen to form hydrochloric acid. Water, when boiled, dissolves twice its own bulk of chlorine at the ordinary atmospheric temperature and pressure. Chlorine is electro-positive in oxygen compounds, and electro-negative in all others. It supports combustion, especially in the cases of powdered antimony and phosphorus. Its most distinctive characteristic is its power of destroying vegetable colours, which it does by depriving them of more or less of their hydrogen. It possesses active chemical properties, and combines directly at ordinary temperatures with nearly all metals, many metalloids, and many compound bodies; at higher temperatures it combines with additional bodies, such as sulphur, selenium, boron, silicon, but not with carbon, except indirectly.

Section II.—Compound Gases.

Marsh Gas. (H_4C or C = 75; H = 25. *Syn.* Light Carburetted Hydrogen; Fire damp; Hydride of Methyl.)

This gas more nearly resembles hydrogen in its properties than any other compound gas, and is a very common natural product. It is colourless, tasteless, and inodorous; possesses little chemical activity, and yields a flame which has little luminosity. Its sp. gr. is ·5576 (8·05), or rather more than half as heavy as air; according to calculation the

figures should be ·5536 (8). It is sparingly soluble in water, which takes up about 5·4 per cent. by volume at 32° F. At a white heat it is decomposed into carbon and hydrogen. Its refractive power (air = 1) is 1·504; its index of refraction, 1·000443 (3·21); and its specific heat for equal weights (water = 1) is ·5929 (·174), or, theoretically, ·425 (·125). This gas is nearly always formed when organic matter decays in the presence of water. The little bubbles of gas so common in stagnant and in marsh water is mainly composed of it; hence the derivation of one of its names. Coal-beds are immense masses of moist vegetation undergoing slow decomposition, and hence they are an abundant source of marsh gas, or fire damp as it is called by the miners. It is not combustible in itself, but it becomes so on being mixed with twice its volume of oxygen. This mixture when heated explodes, and produces one volume of carbonic acid, and two volumes of steam. This is attended with condensation of volume, both products being heavier, that is, more dense. The consequence is a rush of air to fill up the partial vacuum, which is generally so powerful as to knock the miners violently against the floor and sides of the passages. In the conversion of the fire damp into carbonic acid and water, ten times its bulk of air is deprived of its oxygen, so that the resulting atmosphere is irrespirable, and is the well-known *choke damp* of the miners. There are numerous localities where light carburetted hydrogen issues from crevices in the earth, and which, from its ready inflammability, has given rise to many of the so-called burning springs. In some cases it is pure, in others it is mixed with bitumen, but in all there is reason to believe it has originated either from organic matter, or from deposits of rock salt; the crepitating salt of Wieliczka owes its property to the escape of compressed marsh gas. The most remarkable of these burning springs are at Fredonia, New York; St. Barthelemy, department de l'Isere, France; Mount Chimiere, Asia Minor; Brosely, Lancashire; Ludovici mine, Szlatina, Hungary; Tseu-lieou-tsing, China; and in the old tem-

ples of the Guebres, or fire-worshippers, near Baku. It is probable that most of the *salses* or mud volcanoes are due to the accumulation and escape of carburetted hydrogen. They generally occur in groups, and are frequently arranged in lines. Their eruptions resemble volcanic action on a small scale, but they do not occur in volcanic regions. The flames from them have little luminosity, and can only be seen at night from any distance. They abound in Italy along the northern slope of the Apennines; at Maculaba in Sicily; in the Crimea; the Taman peninsula; the neighbourhood of Baku; and in different parts of Asia, such as Bengal, Java, and China.

Phosphoretted Hydrogen. (H_3P.)

This gas is produced naturally under somewhat similar circumstances as the one just noticed, viz. where organic matter containing phosphorus compounds, such as fish, is undergoing moist decomposition. It is colourless, possesses a disagreeable garlic-like odour, and is the cause of the peculiar odour of stinking fish. It is soluble in about fifty times its volume of water, and its sp. gr. is 1·214 (17·5). It seldom occurs pure, but is usually mixed with the vapour of phosphide of hydrogen, a liquid having the composition indicated by the formula H_2P,* which renders it spontaneously inflammable in air. The ignition of this gaseous mixture on its escape from water into the air is believed to be the explanation of the phenomenon known as ignis fatuus and will o' the wisp.

* This is the formula given in Watt's Dict. of Chemistry, and by most chemists. If its specific gravity were known, some clue might be given to the true formula. There seems to be much reason to believe that its vapour density is greater than that of phosphoretted hydrogen, since H_2P is a liquid at the same temperature at which H_3P is a gas. It appears to be a rule that the density of substances composed of similar elements at a given temperature is greater in proportion to the number of atoms contained in 1 volume of its vapour. Many examples of this may be found amongst the compounds of hydrogen and carbon, of oxygen and nitrogen, &c. If H_3P, a 4 atom phospho-hydride, is a gas at ordinary temperatures, it is not likely that H_2P, a 3 atom phospho-hydride, would be a liquid. The probability is that it is H_2P multiplied by 3 or more, that is, H_6P_3 or $H_{12}P_6$, &c.

AMMONIA. (H_3N, or N = 83·39; H = 17·61. Volatile Alkali.)

It is gaseous at ordinary atmospheric temperatures and pressures, but is liquefied by a pressure of $6\frac{1}{2}$ atmospheres at 50° F.; and solidified by a pressure of 20 atmospheres at —103° F. It is colourless, possesses an exceedingly pungent odour, and has an alkaline taste. Its sp. gr. is ·5902 (8·5); sp. ht., ·508 (·178); and refractive index, 1·000385 (2·79). It supports neither combustion nor respiration, but is feebly combustible. It is remarkably soluble in water, which dissolves 670 times its bulk at 50° F. It is powerfully alkaline; restoring the blue colour to litmus paper reddened by an acid, and neutralising the strongest acids. Air contains an infinitesimally small proportion as a carbonate; rain, river, and sea water contain larger proportions of it as nitrate. It occurs in many mineral springs; in nearly every kind of clay, soil, and iron ore; in the sap of plants, and in the fluids and excrements of animals. It enters into the composition of sal-ammoniac and ammonia-alum, and is formed either in a free or combined state by almost all nitrogenised organic substances when they putrefy.

SULPHURETTED HYDROGEN. (H_2S or S = 94·18; H = 5·82. Hydrosulphuric Acid; Protosulphide of Hydrogen.)

A compound which is colourless and gaseous at ordinary temperatures, and under ordinary pressure. It possesses a peculiar fetid nauseous odour and taste, characters by which its presence is readily detected in rotten eggs. It is produced wherever organic matter, water, and sulphates, such as that of lime, remain long enough in contact; is evolved from fumaroles and volcanoes; and is contained in solution in many mineral waters, such as those at Harrogate, Bareges, Bagnères, D'Enghien, Montmorency, and elsewhere. It is contained in the pores of certain mineral substances, such as limestones, dolomites, and marls, from which it may be disengaged by friction or percussion. In nature it is always asso-

ciated with water; and occurs in the exhalations of volcanoes, when in their least active state. The active volcanoes discharge hydrochloric acid, and seldom or never sulphuretted hydrogen. This latter gas unites with many alkalies and alkaline earths, and gives rise to sulphides when it acts on metallic oxides. It is decomposed by nearly all oxidising agents, the oxygen of which unites with the hydrogen to form water, while the sulphur is deposited in a free state. The aqueous solution is thus acted upon by air; but when it is mingled with a gaseous vapour, and in that form exposed to air or other oxidising agents at a temperature of about 200°, it is converted into sulphuric acid. It reddens litmus paper, but not strongly; is soluble in about one-third of its bulk of water, and has a specific gravity of 1·178 (17). It is readily inflammable, burning with a bluish flame. It is liquefied by a pressure of 17 atmospheres at 50° F., and solidified by a temperature of —121° F. It is most readily detected by its blackening action on silver and lead.

HYDROCHLORIC ACID. (HCl or H = 2·74; Cl = 97·26. Chlorhydric Acid; Muriatic Acid gas.)

It is a colourless, pungent smelling, acrid tasting gas, which extinguishes burning bodies, reddens vegetable blues strongly, and has a great affinity for water. Water absorbs about 450 times its volume of the gas at 60° F. Its sp. gr. is 1·274 (18·25); sp. ht. for equal weights (water = 1), ·1845 (·045). It is condensed to a colourless liquid by a pressure of 40 atmospheres at a temperature of 50° F. It is discharged by volcanoes in eruptions, and is rapidly absorbed by the water formed from the steam discharged at the same time, so as to give rise to rivulets of dilute hydrochloric acid. It exists in the thermal waters of Chucandiro, Guniche, San Sebastian, and other places between Valladolid and Lake Cusco, Mexico; in the pores of certain partially decomposed lavas, such as those of Vesuvius; in the dolomites of Puy Sarcouy, Auvergne; and in certain saliferous deposits, such as the

salt mines of Wieliczka, in Galicia; of Aussee, in Styria; and of Kreutznach, in Rhenish Prussia.

SULPHUROUS ACID. (SO_2 or S = 50·14; O = 49·86.)

Colourless, permanently elastic, and gaseous at ordinary temperatures and pressures, it condenses to a liquid when exposed to a cold of about —7° F., and solidifies at —105° F. The gas has a pungent and suffocating odour, and a disgreeable acid taste. Water dissolves about 35 volumes of it at 60° F. It bleaches some vegetable and animal substances; its sp. gr. is 2·23 (32), and when moist it readily combines with oxygen to form sulphuric acid. It combines with many bases, and forms sulphites. It is formed in volcanoes under somewhat similar conditions as sulphuric acid, but at temperatures not less than 190° or 200° F.; so that, generally, the sulphurous acid of volcanoes is the result of rapid oxidation, and the sulphuric the result of the slow oxidation of sulphuretted hydrogen. Sulphurous acid is abundant in Iceland, at Teneriffe, at Etna, at Stromboli, and at several of the volcanoes in Japan and the Andes; but it is rare at Vesuvius, where hydrochloric acid is the predominant gas. It is always disengaged by active solfataras, and is frequently absorbed by waters flowing in their vicinity, which then constitute the sulphurous acid waters of the grottoes at Santa Fiora, Etna, and elsewhere.

CARBONIC ACID. (CO_2 = 27·27 C. and 72·73 O.)

A colourless, transparent gas, having a sp. gr. of 1·526 (22). It has an astringent taste, reddens litmus paper when moist, extinguishes flame, and is irrespirable. It has been liquefied by a pressure of 36 atmospheres at a temperature of 32°, and solidified by the intense cold produced by the rapid evaporation of the liquid acid. It dissolves in about its own weight of water. It exists in large quantities in nature, but the atmosphere generally contains about 4 parts in 10,000; it is held in solution by nearly all spring waters; it forms nearly one-half by

weight of all limestones and marbles, and a smaller proportion of numerous other carbonates. It is formed during the processes of fermentation, respiration, putrefaction, and combustion. The growing parts of plants decompose it under the influence of daylight and sunlight. It issues from fissures in the ground, chiefly in volcanic regions, and is ejected in vast quantities from active volcanoes. Its weight being greater than that of air, causes it to accumulate more or less at the bottom of wells, mines, quarries, and caverns, especially in limestone districts, where it is emitted from fissures. Some of the places where it has thus accumulated have acquired considerable notoriety from the poisonous effects of the gas, such as the Grotto del Cane, and others near Bolsena, in the Roman States; Aubenas in the department of the Ardèche; at Perols, near Montpellier; at Mount Joli, near Clermont Ferrand; at the old abbey of Laach, on the Rhine; and at Typhon, in Cilicia. It is particularly abundant in the craters of extinct volcanoes, and in old solfataras, of which the valley of Poison, in Java, is a good example.

Atmospheric Air.

It consists of several gases, the principal being oxygen and nitrogen, mechanically mingled, and not chemically combined. As a compound it is transparent, blue (when great thicknesses are seen through), and about 816 times lighter than water at a temperature of 60° F., and under a pressure of 30 inches. Under such circumstances 100 cubic inches of dry air weighs 31·074 grains. The atmosphere has nearly the same composition under all normal circumstances, but each of its constituents varies within certain narrow limits. Perfectly dry air, deprived of its carbonic acid and ammonia, consists on the average of 20·96 per cent. by volume of oxygen, and 79·04 of nitrogen. But besides these, ordinary air contains from 3 to 5 volumes of carbonic acid per 10,000 volumes of air; about 1·4 per cent. of aqueous vapour, and traces of nitric, hydrochloric, sulphurous, and sulphuric acids, ammonia,

carburetted hydrogen, and organic impurities. Although the quantities of these last ingredients are relatively very small, yet they ought not to be overlooked, since they exercise great influence on inorganic as well as organic substances. As air is a mechanical mixture, its properties belong to its ingredients separately rather than to itself as a whole. Water dissolves the principal elements of air, oxygen and nitrogen, in the proportion of two volumes of oxygen to one of nitrogen. The air of waters is consequently essentially different from atmospheric air. The sp. heat of air is ·2374 (Regnault) (·069), and its refractive power ·000589 (4·2). Air is frequently taken as unity in comparing its specific gravity, specific heat, refractive power, &c., with those of other gaseous bodies; but the relation between such bodies is better seen when hydrogen is unity.

Section III.—Water.

This chemical compound (H_2O) consists of two volumes of hydrogen and one of oxygen, or of 89 parts by weight of oxygen and 11 of hydrogen. It exists in nature in three different states, and may be either aeriform, liquid, or solid

Aeriform Water.—Vapour, Steam.

Aqueous vapour is constantly being given off in large quantities from seas, lakes, rivers, and other masses of water, and in small quantities from snow and ice. The air is capable of retaining certain amounts of this vapour at certain temperatures. When the air is saturated, it is said to have a humidity of 100. If its temperature is raised, it has the power of taking up more vapour; but its capacity is lessened by reduction of temperature. When the saturated air has its temperature lowered, a portion of the vapour is deposited in the liquid or solid form, either as cloud, dew, rain, snow, or hail.

Aqueous vapour is also emitted from fissures in the ground, some of which are connected with centres of volcanic action, while others are connected with limestone

formations far distant from any volcano. Steam, that is, aqueous vapour formed at a high temperature, and under a considerable pressure, escapes in abundance from active volcanoes, and is discharged from openings in the ground known as *fumarolles* and *soffioni*. These vapours are generally mixed with gases, such as hydrochloric and sulphurous acids, and sulphuretted hydrogen, or with the vapour of solids, such as those of boracic acid in the lagoons of Tuscany.

Water.

The term water is generally restricted to the liquid form of this substance. It is (when pure, and in thin masses) colourless, transparent, tasteless, and inodorous. It is generally taken as the standard of comparison in investigating various physical properties of liquid and solid substances, and its specific gravity, &c., is said to be 1 or unity. The English unit of weight is the weight of a cubic inch of water at 62° F., and when the atmosphere supports 30 inches of mercury; this amounts to 252·458 grains; a cubic inch of dry air, which is the standard for gases and vapours, weighs ·31 grain; consequently water is about 816 times heavier than air. The English unit of heat is the quantity of heat required to raise 1 lb. of water (weighed in vacuo, and at about 60° F.) from 60° to 61° F., which is equivalent to a force represented by the fall of 772 lbs. from a height of 1 foot; or, to express the same thing in another way, to a force that will raise 772 lbs. to a height of 1 foot. The French unit of heat is the quantity required to raise 1 kilogramme (2·2 lbs.) of water from 0° to 1° C., which is equivalent to 423 kilogrammetres. The relation between the two units may be thus expressed:—

423 kilogrammetres = 3045 ft. lbs.
English unit of heat = 772 „
„ „ = 107·2 kilogrammetres.

The proportion between them is consequently as 1 is to 3·93.

In Chapter I. reference is made to the inconvenience

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of having two standards of weight—one for gases, and the other for liquids and solids; so that we need not further enlarge upon the subject here. Suffice it to say, that hydrogen at 0° C., and under ordinary atmospheric pressure, being 1, the same volume of water will weigh 11,178 times as much at 62° F. ($16\frac{2}{3}$° C.), 11,188 at 32° F. (0° C.), and 10,179 times as much at 100° C. (212° F.)

Water conducts heat and electricity badly; is very slightly compressible, and has its maximum density at 39° F. It combines with or absorbs the great majority of substances; and consequently pure water never occurs in nature. This power of absorption, combined with its universal distribution, renders it the principal agent by which most of the chemical changes in nature are effected, and the study of the chemical action of natural waters throws great light, not only on the formation and decomposition of minerals, but also on the formation and decomposition of organised beings. This is a subject of the highest importance to the mineralogist and lithologist. We cannot enter into details here, but one or two illustrations must suffice. Oxygen, in the dry state, has very little chemical activity at ordinary atmospheric temperatures, so that iron—and, indeed, most of the metals—are unaffected by it. By far the greater number of minerals are either oxides or oxides combined with something else; so that nearly all metallic compounds must have been formed at a high temperature if dry oxygen only had existed. When, however, the oxygen is moist or dissolved in water, it possesses considerable chemical activity at low temperatures, and it is by moist oxygen that the oxidising processes of nature are effected. Carbonic acid is another powerful mineralising agent; but so long as it is dry it does not even possess acid properties. All native carbonates are formed from aqueous carbonic acid. These two gases are contained in nearly all spring waters, so that wherever water flows over or through the rocks elevated above the sea, there is a constant tendency to the formation of oxides and carbonates. If, moreover,

it is borne in mind that water is essential to the formation of nearly all silicates, since silicic acid will not combine at ordinary temperatures unless it is dissolved, the important part it plays in the formation of minerals will be readily understood. This is shown independently by the composition of the minerals themselves, and by rocks which are aggregated minerals. A great many minerals are hydrates, such as the zeolite family, or contain more or less water in mechanical combination, as in most decomposing minerals. The rocks—even the denser ones, such as granite—are more or less saturated with water; and, according to Delesse, there is more water below the surface of the solid part of the earth than there is above.

Ice, Snow, Hail.

These represent the solid crystalline form of water. The crystals belong to the hexagonal system, and are frequently arranged into composite masses of remarkable beauty and variety of form, in which every line, every face, and every crystal, is inclined towards its neighbour at an angle of 60°, or some multiple thereof.

CHAPTER III.

Native Metalloids and Metals.

Carbon. (C. Atomic weight, 12.)

Carbon and silicon are amongst the commonest of the elements, and, at the same time, they are amongst the most difficult to give an account of, partly in consequence of the great variety of form in which they exist, and partly on account of their properties not being in apparent harmony with those of the other elements. One illustration of this apparent want of harmony appears in the case of specific heat. When the specific heat of nearly all the elements is multiplied by the atomic weight, the product is a number approximating to 6·4; but the numbers yielded by carbon, boron, and silicon differ widely amongst themselves, and are at the same time much less than 6·4. There is undoubtedly some explanation for these exceptions, but as yet no satisfactory explanation has been proposed.* We would suggest that it may be intimately connected with the fact that the densities of carbon, boron, and silicon are very much greater relatively to their atomic weights than those of any other elements. Glucinum also is an exception. It evidently belongs to the same category as boron, carbon, and silicon, as regards its sp. ht. This is not the place for entering into the evidence in support of our suggestion, for it is only a suggestion; but a few figures will bring out more clearly what we have indicated above as to the relation between the atomic weights, the density, and the specific heat. The figures are taken from Watt's "Dictionary of Chemistry, art. Heat," but the parallelism would

* This was written before the author had ascertained that Berthelot had pointed out (An. de Chemie. [4] ix. pp. 469-480, 1866) that the anomalous properties of carbon are due to its high state of condensation.

be better shown if the specific heats were those of the elements in corresponding states of condensation when not near their boiling or melting points. By corresponding states of condensation we do not mean having the same density, but having a density the same number of times greater than their atomic weights. The specific heats, moreover, should be those referring to the same temperature or the same limits of temperature. The specific gravities are expressed according to the hydrogen scale.

Substance.	Atomic weight.	Specific gravity.	Specific heat multiplied by atomic weight.	Specific gravity divided by atomic weight.
Sodium	23	10,851	6·75	471
Phosphorus (white)	31	16,934	5·85	540
Sulphur (prismatic)	32	22,132	6·43	690
Carbon (anthracite)	12	14,531	?	1,204
„ (graphite)	„	23,362	2·41	1,946
„ (diamond)	„	39,346	1·76	3,262
Boron (crystallised)	11	29,368	2·75	2,699
Selenium	79	48,065	6·02	608
Zinc	65	79,353	6·21	1,220
Copper	63·5	99,831	6·04	1,490
Bismuth	210	109,879	6·48	520
Platinum	198	239,209	6·20	1,258

Carbon, as is well known, exists in many different forms, mainly characterized by their different densities. Charcoal powder is light; coal, anthracite, and graphite, which are almost pure carbon, are much heavier and harder; while the diamond is still heavier, and the hardest substance known. The different densities appear to be due to the different circumstances under which the carbon has been separated from its compounds. Thus the light variety, or *soot*, is obtained when the carbon is separated from flames when under ordinary atmospheric pressure; light charcoal is obtained when wood is heated under slight pressure, and with a limited supply of air; dense charcoal is produced when wood is raised to a high

temperature in a closed vessel, in which process it is necessarily exposed to great pressure by the tension of the gas enclosed with it; graphite is the form which the carbon takes when large masses, several tons weight, of liquid iron, or of the carbon-containing fluids used in the manufacture of alkalies, &c., are subjected to certain modes of treatment which cause the separation of the carbon. This carbon is generally under the pressure of the superincumbent and surrounding fluid. The same relation between density and pressure seems to obtain in the form of carbon as known to the geologist and mineralogist. Thus we generally find the light peat bogs on or near the surface; lower down come the lignites; still lower, the brown coals; next, the soft coals; followed by the hard coals; beneath them are the anthracites; lower still the graphites, and probably the diamonds come below all. Hence it is that, generally speaking, the coals are of greater geological age than the lignites, anthracite than coal, and graphite than anthracite. But such relationship in age will only hold good on the same area; not between different areas, since anthracite is known of far more recent formation than the ordinary coal-fields, and other apparent exceptions exist. In most, if not all, cases they are fully explained, if the pressure to which the coal, or whatever it may be, has been subjected is taken account of. Thus there are cases in which the bands of coal or anthracite are close to the present surface, or with not more than a few hundred feet of rock above them; although, probably, such bands were at one time covered by many hundreds of feet of rock, which has been carried off by the denuding agency of rains, rivers, floods, and oceanic waves acting for enormous periods of time. With these general considerations we will pass on to the descriptions of graphite and the diamond, disregarding lignite, coal, &c., as belonging to lithology, or palæontology, rather than to mineralogy.

Graphite (Black Lead; Plumbago) is carbon containing from 1 to 5 per cent. of mechanical impurities, generally lime, iron, and alumina. It occurs either as

amorphous masses or in crystalline flakes. The crystals are six-sided laminæ, having a distinct cleavage parallel to the base. The specific gravity varies from 1·8 to 2·4; the hardness from 1 to 2 (in the amorphous graphite); and the colour from dark iron black to a steel grey. Both varieties make a dark streak on paper, but the amorphous form being the softer and darker of the two, is alone fitted for the manufacture of pencils. It is infusible, a conductor of electricity, and combustible, but at a temperature far higher than is required for coal, and lower than that required for the diamond. The crystallised variety is found in few places only, and in small quantities. Sometimes it is embedded in quartz, as in Ceylon and Australia; sometimes in gneiss, as at Stourbridge, Massachusetts. The amorphous graphite is more abundant, and occurs as small scales and grains, large nodular masses, or in beds. The former two are met with in the sedimentary deposits derived from the degradation of the older rocks, while the latter are generally associated with the more highly crystalline limestones and mica-schists. The more important deposits are situated at Griesbach, near Passau; in the Semipalatinsk district of Western Siberia; on the banks of the Lower Tunguski, and at Mount Balagool, in Eastern Siberia; near Swojanow, in Bohemia; and in the Laurentian rocks of the townships of Burgess, Lochaber, and Grenville, in Eastern Canada. The deposit at Borrowdale is perhaps the best known to most English readers, but it is now nearly worked out, and is inferior to most of the localities mentioned above as regards quantity, although it is still superior to most of them as regards quality.

Diamond.—The diamond is almost pure carbon, containing an infinitesimal quantity of impurity in the coloured specimens; of which impurity silica and iron are the predominating ingredients. It is said that occasionally the ash left in burning some diamonds contains what appears to be something like vegetable structure. The diamond occurs in cubes, octahedrons and other forms belonging to the regular system; two of the more complicated of which

are represented in Figs. 29, 30. Its specific gravity varies from 3·48 to 3·55; its hardness is 10; its index of refraction, 2·439; and its lustre adamantine. When pure it is colourless, but yellow, green, rose, blue, brown, and black diamonds are also found. It will not conduct electricity; is infusible by the highest artificial heat yet obtained, insoluble in any liquid, and incapable of combining with oxygen except at the highest obtainable temperatures. Its union with oxygen results in the formation of common carbonic acid. When exposed to a very strong heat, in an atmosphere free from oxygen, it swells up into a black mass like graphite or coke.

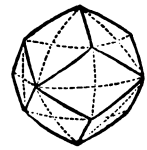

Fig. 29.

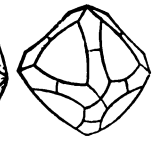

Fig. 30.

The hardness of the diamond being greater than any other substance, it can only be cut or polished by itself. The polishing of diamonds is effected by rubbing the diamond against a steel wheel, having the edge covered with diamond dust. The rarity of the diamond, combined with its peculiar properties, has imparted to it a factitious value and interest, far beyond that of any other mineral; but to the mineralogist the diamond is one amongst many other stones which have an equal claim upon his attention.

The diamond is usually found in alluvial deposits derived from older rocks. The best are brought from India and Brazil. In India the principal localities are near Golconda, where they are obtained by washing the sands. In Brazil the principal localities are in the provinces of Minas Geraes, and St. Paul, where they are also obtained by washing the sands of the larger rivers. Diamonds are also found in the Ural Mountains; in North Carolina, California, Australia, S. Africa, Borneo, and Sumatra. Occasionally the diamond is found *in situ;* the rock is in nearly all cases a more or less dense sandstone, which is usually called by the name of *itacolumite.*

SULPHUR. (S. Atomic weight, 32. *Syn.* Brimstone.)

Like many of the gases noticed in the previous chapter, sulphur, in the native state, is most commonly found in connection with volcanoes; but as it is a frequent product of the decomposition of sulphuretted hydrogen, it also occurs in all the lithological stations where that gas occurs. Sulphur exists in three modifications, viz., (1) in crystals belonging to the trimetric or rhombic system, (2) in acicular crystals belonging to the triclinic system, and (3) in an amorphous state. The first and third only are found native. The most common form of crystal is the right rhomboidal octahedron, represented in Fig. 21, Plate I.; but upwards of 40 other forms (most of which are derived from the octahedron by the truncation of the solid angles and edges) have been described by Prof. Maravigna. The reason why the second modification does not occur in nature is, that it remains stable only at about the temperature of 231° F., and that when the temperature is reduced much below this point it is transformed into crystals like those found in native sulphur. The localities from whence native sulphur is obtained are always much below 231°. The amorphous form is the most abundantly met with, either as compact masses, small fragments, small grains disseminated in other minerals, or a yellow slightly adherent powder lining cavities in lavas.

Sulphur, when pure, is of a yellow or honey-yellow colour; very fragile; and breaks with a conchoidal fracture, and a vitreous or resinous lustre. It is generally more or less translucid, but sometimes may be quite opaque. Its sp. gr. is 2·1 (23,473), which is rather higher than that of molten sulphur; its sp. ht., ·2026 (·0295); its index of refraction, 2·115 (8079); and the angle of the optic axes from 70° to 75°. It fuses at about 231° into a transparent citron yellow fluid, which on further heating to 310° becomes slightly viscid, and changes to a brownish colour. At 428° it is blackish-brown and semi-solid; and at 752°, in a closed vessel, it melts, boils, and gives off an orange-red vapour. When this is quickly

condensed it forms flowers of sulphur, which is the state in which it occurs in volcanic lavas. Its streak is yellow, and sometimes reddish or greenish. Sulphur possesses a slight taste, and a slight odour when rubbed; it is very combustible, and in combining with oxygen forms sulphurous acid, which burns with a bluish flame, and gives off acrid suffocating fumes; it is a bad conductor of heat and electricity, and has a specific magnetic power of —1·221, water being unity. It is soluble in bisulphide of carbon, chloride of sulphur, benzene, naphtha, the fatty oils, oil of turpentine, &c.; but insoluble in water.

The principal deposits of sulphur are associated either with active volcanoes or beds of gypsum. Nearly every active volcanic region yields it in greater or less abundance. The larger proportion of the native sulphur of commerce is brought from the volcanic districts of Sicily, Solfatara near Naples, and the crater of Vulcano one of the Lipari Islands. The more important additional localities are Iceland, Teneriffe, New Zealand, and Java, in connection with volcanoes; and at Conil near Cadiz, Bex in Switzerland, Cracow in Poland, and elsewhere in connection with gypseous beds. There are also extensive sulphur mines in Formosa, and Persia. It would be impracticable to mention all the localities where small quantities of sulphur are found, but Poldice and Nangiles mines in Cornwall, Bole Hill in Derbyshire, Dufton in Westmoreland, Alston in Cumberland, Brook-lodge in Galway, and Castle Cara in Mayo, are a few of the best known.

It is hardly known in the older volcanic rocks, and is rarely met with in the older metamorphic rocks; but when it does occur is usually in a granular form, in the most quartzose rocks, such as quartzite, mica-schist, itacolumite, porphyry: but it also exists in metamorphic limestones, such as the saccharoidal marble of Carrara. The largest deposits of sulphur are confined to the more recent sedimentary strata, and are especially associated with the gypsum, limestones, and marls of the saliferous deposits, and with similar rocks of the tertiary,

carboniferous, and silurian epochs. It is frequently met with near thermal waters holding sulphur compounds in solution, and arises from the decomposition either of sulphuretted hydrogen by the combined action of heat and oxygen, or of sulphates by various reducing agents, but mainly organic matter. Its occurrence in marshes, ponds, and other places where animal and vegetable matter is decomposing is due to a similar action. It is frequently met with in metalliferous veins, especially those containing copper pyrites, galena, and gold.

Sulphur combines with numerous elements, forming a class of substances known as sulphides, which have many resemblances to the oxides, and are formed directly either by combination at somewhat high temperatures, or by the action of metals on sulphuretted hydrogen both at ordinary and high temperatures.

Selenium. (Se. Atomic weight, 79·5.)

This is a metalloid which has a close resemblance to sulphur in many of its physical properties, and in its chemical behaviour. It is much more rare, and indeed it is doubtful if it has been found native. Del Rio says he saw it at Culebras in Mexico, and Professor Napoli says it has been found in the Vesuvian lava. It is usually associated with sulphur, with which it appears to form an alloy of an orange-yellow colour, and occurs amongst the volcanic products of the crater of Vulcano in the Lipari Islands, and of Kilauea in the Sandwich Islands; it also occurs in iron pyrites and in coal. The crystals are triclinic.

Selenium is solid at the ordinary temperature; and when heated undergoes modifications according to the temperature. When melted and cooled suddenly it forms a blackish mass of sp. gr. 4·28 (47,481), which is transparent in thin plates, and red by transmitted light; when cooled slowly it forms a mass having a sp. gr. of 4·8 (49,654), and a greyish colour. It fuses at about 422° F., and burns with a reddish-blue flame, giving rise to gaseous oxide of selenium, which is at once recog-

nised by its peculiar odour of horseradish. Selenium is brittle, inodorous, and insipid. It is a bad conductor of heat and electricity; is insoluble in water, but soluble in bisulphide of carbon and the fatty oils. It tinges the blowpipe flame of a light blue colour.

Tellurium. (Te. Atomic weight, 128.)

The only known localities for this metal are at the Maria Loretto mine, near Zalathna, and at one or two other places in Transylvania, where it occurs in small granular masses in quartzose veins traversing sandstone. It was formerly abundant, and was smelted for the sake of the gold it contained. The crystals are sometimes found lining the geodic cavities of quartz, and associated with other crystals of gold and hyaline quartz. They are hexagonal prisms, having the terminal edges truncated. The cleavage is parallel to the faces of the prism. The sp. gr. varies from 6·1 (68,185) to 6·3 (70,421). It is brittle, of a white or pale grey colour, and readily fuses before the blowpipe, when it burns with a greenish flame, and volatilises in a white inodorous vapour.

It is soluble in acetic, hydrochloric, and concentrated sulphuric acids. The specific heat is ·0473 (·0069). It is so bad a conductor of electricity, that it ranks with dielectrics or insulators rather than with the conductors, to which group most metals belong.

Arsenic. (As. Atomic weight, 75.)

This metal is frequent in nature, either in a free state or in combination. It occurs in the ferruginous deposits from mineral waters, most iron ores, and in sulphur. In minute quantities it appears to be very widely diffused. It is usually granular, but sometimes it forms rhombohedral crystals, closely resembling those of tellurium and antimony. By cleavage the octahedron with a rhombic base can be obtained, which is the primary crystalline form of sulphur. The crystals of arsenic form acute truncated rhombohedrons of 85° 4′. Arsenic, like many of the elements already described, has its allotropic con-

ditions, depending upon the circumstances under which it is solidified. When condensed in vapour of arsenic, and near its fusing point, it forms a compact white mass which retains its form when exposed to the air; but when it is mixed with other gases, and is condensed at a temperature much below its fusing point, it forms a grey powder which rapidly oxidises in the air. Its specific gravity is less than that of the compact variety. Native arsenic is generally amorphous, and varies in texture from fine-grained to compact. It is steel-grey in colour, very brittle, of a brilliant lustre on the fresh surfaces, which soon tarnish and blacken in the air, while in water the whole mass is slowly converted into arsenious oxide. When heated, it emits a strong odour of garlic. Its specific heat is ·8140 (·239). It never forms veins, but is frequently met with in veins containing sulphide of silver, grey copper, galena, and especially arsenical nickel and arsenical cobalt. In Norway crystallised beryls are embedded in arsenic.

It forms alloys with many of the metals, amongst which is the native *Allemontite*, which is found at Allemont in the department of Isère, at Andreasberg, Przibram, and other localities. It occurs in veins traversing gneiss and is generally associated with native antimony and antimony ores. In external appearance it resembles native arsenic.

Antimony. (Sb. Atomic weight, 122.)

It resembles arsenic in many of its properties, both chemical and physical. It is rarely found native, but is most abundant as a sulphide. It crystallizes in acute rhombohedrons, having an angle of 87° 35′. The principal cleavages are the same as in the crystals of arsenic, so that from the rhombohedrons we may obtain crystals closely resembling the octahedral form of sulphur. It occurs in veins traversing gneiss, especially such as contain arsenical ores. The colour is silver white, the lustre high, the fracture varies from laminated to granular, and the specific gravity from 6·7 (74,892) to 6·8 (76,009). It

fuses at 778° F., oxidises when melted in presence of air, but not at ordinary temperatures. It is very brittle, and has a hardness of 3· or 3·5. There are two or three allotropic forms known to the chemist, which vary considerably in density, and are obtained under different circumstances. The changes which one of these allotropic forms undergoes is very similar to what occurs in sulphur, selenium, and some of the metals. The specific heat of antimony is ·05077 (·0073).

BISMUTH. (Bi. Atomic weight, 210.)

When pure it resembles antimony, but may be at once distinguished by its roseate tinge. It forms crystals which, at first sight, appear to be cubes, but which are really acute rhombohedrons, having an angle of 87° 40′, and a principal axis which is to the secondary axes as 1·305 to unity. It has also been found in octahedral and tetrahedral crystals. Its cleavages are nearly the same as those of antimony. Crystals, however, are rare, the usual form being feathery and dendritic aggregations. The hardness of bismuth is 2·5, and the density varies from 9·6 (107,308) to 9·8 (109,504). This variation is due to a different molecular condition. Thus, cast bismuth has a specific gravity of 9·86, but when subjected to a pressure, its density is lessened. In one experiment a pressure of 200,000 lbs. reduced the specific gravity to 9·55 (106,749). Bismuth is soft, sectile, brittle when cold, but slightly malleable when heated. It melts at about 507° F., so that it is readily fusible by the blow-pipe. It volatilises in dense white fumes; it expands when passing from the liquid to the solid form, and, as it imparts the same property to many of its alloys, they are frequently employed in cases where sharp impressions are wanted in cast metal, especially in typefounding. One of its principal uses is for making the *solder* employed by plumbers, which is composed of one part of bismuth, five parts of lead, and three of tin. It also enters into the composition of "fusible metal," of which the spoons are made that melt when placed in hot tea. This latter alloy

is composed of two parts of bismuth, one of lead, and one of tin, and melts at 200° F. Its melting-point may be still further reduced by the addition of a little mercury. Bismuth remains unaltered in dry or moist air, but is slowly oxidised under similar circumstances when in contact with water. It burns with a bluish flame in air, and decomposes water at high temperatures. It is readily attacked by nitric acid, but not by sulphuric or hydrochloric acids. Native bismuth is seldom pure, and usually contains small quantities of arsenic, tellurium, selenium, and sulphur, with which it forms alloys. It is found in a clay slate and gneiss (associated with silver, lead, zinc, cobalt, or nickel), in several localities, as for instance, Cornwall, Cumberland, Saxony, Bohemia, Carinthia, Norway, Sweden, and Bolivia. In the last-named country it is associated with crystals of gold. The richest mines are those of Saxony; but a vein, three feet wide, has been opened in the Atlas mine, Devonshire, which consists of $\frac{1}{16}$ part by weight of bismuth.

Maldonite is a native gold-bismuth alloy. *Tetradymite* is a second native alloy composed of variable proportions of bismuth and tellurium. Its crystalline form is that of an acute rhombohedron, and its crystals are often aggregated into groups of four, from which circumstance it derives its name. It is similar in colour to lead or tin, soft and flexible in thin slices, easily fusible by the blowpipe, and, when heated in the air, gives off fumes of telluric oxide. Some of the varieties contain selenium, and give off the peculiar odour of oxide of selenium. The specific gravity is 7·4 (82,717), and in some instances even higher. There are several varieties, but the principal three are those which contain—(1) sulphur only as a secondary constituent; (2) sulphur and selenium; and (3) sulphur, selenium, and silver. Tetradymite is rare; it occurs in fissures in a trachytic conglomerate in Hungary; in saccharoidal limestone in Brazil; associated with molybdenite and chalcopyrite in Norway; in copper lodes, traversing gneiss, in Sweden; and under similar circumstances in other countries. According to Balch, the

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tellur-bismuth from Dahlonega, Georgia, U.S., is a definite chemical compound and not an alloy.

Tin. (Sn. Atomic weight, 118.)

The solid elements which have already been described in this chapter, are linked together by certain characters which distinguish them as a group from those which we are about to notice; the most prominent amongst these are brittleness combined with comparatively low specific gravities, ready fusibility, feeble conductivity of electricity, and somewhat similar crystalline form, combined with similar chemical behaviour. It is doubtful if tin does occur native. It is said to have been met with in the Cornish tin mines; in the auriferous sands of Miask, Siberia, where it is mixed with small quantities of lead; and in French Guiana. It is a white metal, sometimes slightly tinged yellow; but readily tarnishes in air, and becomes bluish grey. Beyond this it is scarcely affected by exposure to the atmosphere or moisture. When rubbed it emits a peculiar odour. It is brittle near its fusing point, but possesses a moderate degree of tenacity and ductility at ordinary temperatures. It conducts electricity and heat; but there are many metals which are superior to it in these points. It crystallises in small octahedrons with a square base truncated on the basal edges; and these are frequently aggregated in linear or dendritic groups. Its sp. gr. is 7·292 (81,519), and sp. ht., ·0562 (·0082). It is strongly affected by dilute, but not at all by concentrated, nitric acid. Hydrochloric acid dissolves it with evolution of hydrogen. Hot sulphuric acid, but not cold, combines with it to form a sulphate. The fused alkalies oxidise tin, hydrogen being evolved. The principal tin mines are in Cornwall, Banca, Malacca, Saxony, and Austria, the chief ore being the oxide or *cassiterite*. It is used as a coating for the protection of other metals, such as copper and iron, and as tin-foil. When alloyed with mercury it forms the tin amalgam used for covering the backs of the glass in mirrors.

Silver. (Ag. Atomic weight, 108.)

Silver, which is found almost pure in nature, is white and malleable; rather harder than gold, but softer than copper; tenacious; ductile; with a sp. gr. of from 10·3 (115,123) to 10·5 (117,369), and a hardness of 2·5. It does not oxidise at ordinary temperatures, but owing to its strong affinity for sulphur it is liable to become tarnished, especially when it is situated near cavities in veins, or when it lies near the surface of the earth; the streak, however, is always silver white. The crystals, which belong to the monometric or regular system, are usually octahedrons (Fig. 31), without any apparent cleavage; they are often aggregated into mossy, arborescent, or filamentary masses, and occasionally into solid blocks of great weight. The mines at Kongsberg, in Norway, now under water, formerly yielded a block weighing 500 lbs.; a vein at Schneeberg, in Saxony, yielded a mass which, when smelted, produced 44,000 lbs. of pure metal; and the mines of Huantaja, in Peru, have afforded a specimen weighing over 8 cwt. The native copper of the Lake Superior district is frequently penetrated by veins and threads of almost pure silver. The most common gangues for silver are calcspar, quartz, and barytine. It is nearly always accompanied by some silver-compound, especially sulphide of silver (argentite). It occurs in thin laminæ in fossil wood, under circumstances which seem to indicate that it has been reduced from the sulphide. Small quantities of silver have been found in Cornwall, and, indeed, in almost every country where metamorphic rocks abound. At one time a considerable quantity was raised in Scotland, and converted into coins; and some of the lead and copper mines of France still yield a good deal of silver. The European silver ores are generally richer than those of South America; but the latter are the more productive on account of their greater abundance, and the larger scale on which they can be worked. Most of the richest

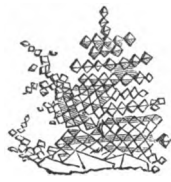

Fig. 31.

silver mines occur in Mexico, Peru, and Chili, where thousands of veins intersect the rocks. The most remarkable is that of Guanaxuato, which has a thickness of 150 feet, and is worked along a length of eight or nine miles. The Potosi mine, in Bolivia, was formerly the richest in the world; but the richness of its veins has lately fallen off considerably. The Guanaxuato vein has been eclipsed by the Comstock lode. About 12,000,000 lbs. of silver are annually obtained.

LEAD. (Pb. Atomic weight, 207.)

It possesses a highly metallic lustre, considerable malleability and ductility, but little tenacity. In the presence of air and water it combines with oxygen to form the oxide, and consequently it readily tarnishes when exposed to the atmosphere. Its specific gravity has been stated at from 11·33 (126,646) to 11·44 (127,876) by various observers; its specific heat is ·0304 (·00443); and its melting-point 620° F. It is a feeble conductor of heat and electricity It crystallizes in regular octahedrons, which are sometimes implanted on one another so as to resemble four-sided pyramids; and it also occurs in dendritic masses, small grains, and laminæ. Lead occurs but rarely in the native state, and is nearly always associated, either with the sulphide (galena) or with the oxide, from which it has probably been reduced. Nöggerath reports its existence in a granular fossiliferous limestone at Zomelahuacan, Vera Cruz; Jenzsch, in the amygdaloid near Weissig; Hingenau, in the gold region near Mount Alatau and Ekatherinenburg; Reichenbach, in basaltic tuff at Rautenburg, Moravia, and other observers at other localities. Hydrochloric and sulphurous acids do not act on it when cold, and only slightly when hot; dilute nitric acid forms the nitrate with evolution of binoxide of nitrogen; acetic acid rapidly attacks it in air; and the alkalies do not affect it. It emits a dull sound when a lump is struck by a hammer, but is sonorous when a mushroom-shaped piece is struck. It forms alloys with nearly all metals, and combines directly with sulphur, phosphorus, selenium, and arsenic.

MERCURY. (Hg. Atomic weight, 200. Quicksilver.)

At ordinary temperatures it is fluid, a character which no other metal possesses. The usual properties of a metal are, however, highly developed in it, and when solid it has much resemblance to silver, especially in its high metallic lustre, ductility, malleability, its capability of being cut with a knife, its granular fracture, and its high degree of conductibility of heat and electricity. It crystallizes in octahedrons and needles. It solidifies at —39° F., and boils at about 650°. Its specific gravity is about 13·60 (152,020) at 50°, and about 15·6 (174,376) when solid. It is unaltered by contact with oxygen, air, hydrogen or nitrogen, or when treated with hydrochloric acid; and it is slightly soluble in boiling water, nitric acid, and dilute sulphuric acid. It is often found native, either as globules disseminated through its ores, or in rocks containing them. It occurs in amalgams of silver and gold, and as iodide, chloride, selenide, and sulphide. The last, or cinnabar, is the most abundant, and the native metal is usually associated with this ore under circumstances which seem to indicate that it has been reduced from the sulphide. It occurs in numerous localities in France, Spain, Bohemia, Hungary, Chili, Mexico, Siberia, &c.

Mercury readily combines with most of the other metals, and the compounds thus formed are called *amalgams*. The amalgams with the heavy elements are generally easy of decomposition, and hence it is exceedingly useful for the extraction of gold and silver from their ores or matrices. The mercury picks up the almost invisible specks of gold, and in this way the gold is concentrated into a comparatively small space. By heating the amalgam the mercury is driven off and the gold is separated in a nearly pure form.

Only two native amalgams are known, viz., those with silver and gold. As in all alloys the proportions of the constituents vary, and the properties of a specimen will vary according as the silver, the gold, or the mercury predominates. When the silver is the principal ingredient,

the compound is called *arquerite*; but when the mercury prevails, it is called *native amalgam.* In arquerite having the composition $Hg\ Ag_{12}$ (= Ag 86·5 and Hg 13·5), the hardness is about 2 or 2·5, the specific gravity 10·8 (120,712), and the predominant crystalline form the octahedron; but it frequently occurs in dendritic masses. In native amalgams having the composition $Hg_3\ Ag$, the hardness is about 3, the specific gravity about 14, and the predominant crystalline form is the rhombododecahedron. Native amalgam, however, varies in hardness and specific gravity, and is met with in other forms belonging to the regular system; such as the cube, the regular octahedron, the leucitohedron, a pyramidal octahedron, a pyramidal cube, and a scalenohedron. Beautiful crystals are found at Morsfield and Moschel-Landsberg; at Szlana, Hungary; Almaden, Spain, and at a few localities in France and Siberia. They usually accompany the sulphides of silver and mercury.

The gold amalgams are also variable in composition and properties. Some small yellow crystals found in mercury at Mariposa, in California, had a composition answering to $Au_2\ Hg_3$, and a specific gravity of 15·47 (172,923). A gold amalgam has also been found at Choco, in New Granada, having a somewhat different composition.

Copper. (Cu. Atomic weight, 63·4.)

This metal appears to be widely distributed through nature; and, if some authorities are to be believed, there is scarcely anything in which it may not be found, from animals and plants to sea-water, cheese, milk, iron ore, &c. In many cases the copper found would appear to have been contained in the brass nozzle of the blowpipe, and not in the substance in which it was sought to be detected. W. Lossen failed in seeing any signs of its presence in numerous animal substances, when he used a glass nozzle. The following statement as to its distribution must, therefore, be considered as not entirely free from doubt. It occurs in all iron soils and ferruginous mineral waters; as also in some meteoric irons; in the blood of

some of the mollusca, such as the cephalopods, and of some of the crustacea, such as *Limulus*, and in the blood and liver of some of the higher vertebrated animals. Like most of the native metals it crystallises in the monometric system. The dodecahedron is the predominant form in the Lake Superior district, where crystals of this form occur as much as 1 inch in diameter. The dendritic forms are frequently aggregations of octahedrons. Large masses of this kind are frequent as ramifications through certain rocks; they are generally covered with a superficial coating of greenish carbonate of copper. Siberia and Cornwall are the principal localities from whence the best cabinet specimens have been obtained, but Brazil and the Lake Superior district have afforded the largest masses. For instance, one block has been obtained from the last-mentioned district weighing 3,704 lbs.; while another, found in the Minnesota mine, was 46 ft. long, had an estimated weight of 400 tons, and contained 90 per cent. of pure metal. It is very common for the copper about Lake Superior to be penetrated by threads and scattered grains of pure silver; the same is also the case with the copper from some other countries, as in that from Chili, which occasionally contains as much as 7 or 8 per cent. of silver.

Copper is one of the toughest, most malleable, most ductile, and most tenacious of the metals, and is inferior to silver only as a conductor of electricity and heat. It has a nauseous taste, and emits a disagreeable odour when rubbed. Its specific gravity in the best formed crystals is about 8·94 (99,931), which is that of the purest commercial copper when fused and solidified out of contact with air. When copper is solidified in contact with air, it has a tendency to become vesicular, and, consequently, may have a specific gravity as low as 6 or 7. The specific heat of pure copper is ·095 (Regnault) (·014), and the fusing point is variously stated at from about 1500° F. (Pouillet) to about 2538° F. (Daniell). It has less affinity for oxygen than iron, and combines with it when dry at a temperature near red

heat. In damp air, however, it is readily oxidised at ordinary temperatures, and the oxide formed combines with carbonic acid and yields the green carbonate. The weaker acids have little effect on copper, unless they are assisted by the presence of the air; hydrochloric acid dissolves it when boiled, but not when cold; weak nitric acid acts rapidly on it, forming the nitrate, but strong nitric acid has scarcely any effect. Hot sulphuric acid unites with the oxide formed, and becomes the sulphate. Alkaline and saline solutions oxidise it in the presence of air. It combines directly with mercury at ordinary temperatures, and with all the other metals at a red heat, as also with bromine, iodine, sulphur, selenium, and silicium. Ammonia, in the presence of a small quantity of air, slowly dissolves it, and forms a colourless solution of the suboxide of copper, but with more air a blue solution of the protoxide is formed.

Copper appears to have been one of the earliest metals used by man. In North America, where the native metal is so abundant, numbers of weapons have been found which are formed from the native metal by hammering, and traces yet remain of the excavations made by the natives in some of the copper lodes. These excavations are of great antiquity, since on the rubbish heaps thrown out in making the excavations, large trees are growing, whose age is calculated at about four hundred years, while the trenches themselves are almost filled up with vegetable mould containing traces of the trunks of former generations of trees, associated with the mining implements of the natives, and supporting living trees of considerable ages. The knowledge of melting copper and alloying it with tin, for the purpose of hardening it, appears to have been limited to one or two only of the American tribes. In Western Europe, however, copper was probably used from the first to form bronze. At any rate, all the old weapons of the Romans, Gauls, and other nations existing in Western Europe prior to the Christian era, which contained copper, were largely alloyed with tin.

Iron. (Fe. Atomic weight, 56.)

This is the most useful of all the metals, and it is the most abundant of them. In its purest state it has a close resemblance to pure copper in many of its properties; thus it is exceedingly tenacious, softer than ordinary malleable iron, and the fracture is scaly and slightly granular. The malleability and hardness are not altered by heating it to redness, and suddenly cooling it. But there is this remarkable difference, that whereas a small percentage of carbon has scarcely any influence on the properties of copper, it has a marked influence on those of iron; and it happens that nearly all iron, whether commercial or native, contains more or less carbon, as also other impurities, which tend to modify its properties. Native iron is far more rare than native copper, in consequence of its stronger affinity for oxygen; it occurs in greatest abundance as meteoric iron. Its compounds, however, are widely distributed, and occur almost everywhere; but they are most abundantly developed in the oldest rocks, viz., those belonging to the Laurentian and Huronian series.

The remarkable effect of small quantities of carbon and other impurities imparts to it that varied range of properties which renders it so useful, but this variability renders a description of the properties of native iron difficult. We will, however, notice those of malleable iron, in order that they may be compared with the iron of meteorites. Malleable iron is far more malleable, tenacious, or tough, than cast iron; it is softer, and requires a higher temperature to fuse it. It possesses a grey colour, having a bluish or blackish tinge; a specific gravity varying from 7·3 (81,589) to 7·9 (88,306), and a specific heat of ·113 (Regnault) (·016). Pure iron may be rendered magnetic, but it retains its magnetism less easily than malleable iron, which, in its turn, is more easily magnetised and demagnetised than steel. The hardness of malleable iron varies considerably; and it is but slightly increased by the sudden cooling of the red

hot metal, but the effect is greater in proportion as the amount of carbon is greater. Pure iron is too soft to resist the friction to which ordinary machinery is liable. Malleable iron undergoes no change either in dry air or in water free from air, but when moisture and air are combined it is rapidly oxidised by them, and still more rapidly when carbonic acid or saline substances in solution are also present. When malleable iron contains much more than ·5 per cent. of carbon, it approaches steel in its properties; and when it amounts to 4 or 5 per cent., the metal becomes brittle, and easily fusible, as in cast-iron.

There are two varieties of native iron, known as (1), telluric, and (2), meteoric iron. The first is very rare, but has been found in nodular and stalactitic masses in the midst of oxide of iron minerals at Gross Kamsdorf and Eibenstock, in Saxony; in a vein near Allemont; in the ashes of some volcanoes; and in a thread two inches wide, and traversing mica-slate, at Canaan, in Connecticut. These contain scarcely any carbon, but others have contained so much as to present a steely character. To this latter class belong the specimens found at Labouiche, near Neris, in the department of the Allier, where it occurs in the midst of rocks which have been altered by the combustion of a stratum of coal. The term telluric refers to their mundane origin to distinguish them from the following variety of iron, which is generally admitted to have a non-terrestrial origin.

Some specimens of this class have been seen to fall from the air under circumstances which seem to show that they have come from interplanetary space. They are sometimes almost entirely composed of metal, while in others they consist partly of iron, and partly of a stony matter resembling peridote. The iron is in some cases sufficiently malleable to be welded into a sword, but in others it is too brittle to be so treated. It usually has most of the properties of ordinary bar iron. One amongst several peculiarities is, that it is generally alloyed with a larger proportion of nickel, and may contain a considerable

proportion of silicon, accompanied by a very small proportion of carbon. These characters are not met with in commercial iron, and hence the masses having those characters found in the ground in places far distant from large towns and iron manufactories, are generally inferred to have fallen at some former period, although there is no direct evidence on the point.

This nickeliferous or meteoric iron is remarkable for the parallel striæ, or Widmannstätten figures as they are termed, which are seen when a polished surface has been acted on with an acid. The striæ are grouped in triangles, representing the faces of the octahedron, which is one of the forms assumed by crystallised iron. When ordinary iron is fused in an ordinary furnace, cooled, polished, and treated with acid, these figures do not appear; but when it has been fused at a higher temperature, along with a small proportion of phosphide of iron, these figures can be obtained. They are generally thought to be due to the presence of nickel, but there are a few irons, such as those found at Greenville, in Tennessee, and Claiborne, in Alabama, which contain from 9 to 12 per cent. of nickel, and yet do not show these figures. There is a splendid collection of meteoric irons, or *aerosiderites*, in the British Museum, comprising 80 specimens, varying from less than an ounce to 8,200 lbs. in weight. The most interesting masses are the following:—The mass, weighing 75 lbs., which fell at Hraschina, near Agram, Croatia, in 1751; those which fell at Braunau, Bohemia, in 1847, weighing 33 lbs. and 46 lbs.; that found by Pallas on the top of a mountain near Krasnojarsk, Siberia, with a weight of 1,600 lbs.; that found by Brard at Caille, near Grasse, in the Var department, France; the four enormous masses found in America, viz., one weighing 3,300 lbs. found in Louisiana; a second, weighing 16,000 lbs., found at Bahia, Brazil; a third, found at Otumba, in Peru, which weighed originally 33,000 lbs.; and a fourth, found near Durango, in Mexico, and weighing 44,000 lbs. We may also notice the specimen found in 1861 near Melbourne, Australia,

having a weight of 8,200 lbs. Nickeliferous iron also forms a constituent of many of the meteoric stones.

Palladium. (Pd. Atomic weight, 106.)

In colour it is intermediate between the grey of platinum and the white of silver. Its crystalline form probably belongs to the regular system, since Haidinger has found it occurring native in minute octahedrons; but it is said also to have been found in six-sided tables, easily cleavable parallel to their faces. It is most generally met with in small flattish grains, which have a fibrous radiated structure, in the platiniferous sands of Brazil. It is found associated with gold at Tilkerode, in the Harz; at Zacotinga and Condonga, Brazil; and at Porpez, in South America. Its hardness is equal to 5, or about that of platinum; it is rather less ductile than platinum, and malleable. It is fused with difficulty by the strongest forge fire, but easily by the oxyhydrogen blowpipe. If mixed with sulphur it can be fused at a much lower temperature. It oxidises at lower temperatures than silver, and slowly tarnishes in air; but it is not affected by sulphur compounds. When solidifying it spits like silver. It is more or less soluble in strong hydrochloric, sulphuric, nitric, and nitro-muriatic acids; and most readily in the latter two. A highly polished cup of this metal, weighing upwards of 3 lbs., is in the possession of the French crown. One of the alloys with gold is used for the graduated part of astronomical instruments.

Gold. (Au. Atomic weight, 197.)

Gold is mostly found in the native state, the only exceptions being the gold amalgam found in America, which scarcely appears to deserve the name of a chemical compound, and the alloys with silver, tellurium, &c. Nearly all the native gold contains more or less silver, in proportions varying from a fraction to 36 or 38 per cent.

The sp. gr. of pure gold varies from 19·25 (215, 176) to 19·36 (216, 496). Gold possesses most of the properties characteristic of a metal exceedingly well marked

It is so malleable that it can be beaten out into leaves so thin that 1,000 of them would not exceed a sheet of ordinary writing-paper in thickness; so ductile that a single grain weight may be drawn into a wire 500 feet long; and so soft that it can be cut almost as easily as lead. In a thick mass it is opaque and yellow; when as thin as gold-leaf, it is somewhat translucent, and of a greenish colour by transmitted light; and when reduced to an impalpably fine powder, it is of a ruby red colour. It is volatilised by the heat of an ordinary muffle furnace, and fuses probably at a temperature of about 2,200° F. It is not oxidised or tarnished by air, and is insoluble in all acids but aqua regia, *i.e.*, nitro-muriatic acid. It is readily acted on by chlorine, which converts it into the terchloride; and it forms an amalgam with mercury with great facility. In most of the gold fields large quantities of mercury are used for extracting the gold from the quartzose or earthy gangue in which it is found.

Gold crystallises in forms belonging to the monometric system, such as cubes and octahedrons, but these are rarely found. It occurs in three different groups of lithological situations—viz. (1) veins in metamorphic rocks, especially such as are associated with diorites, porphyries, and serpentines; (2) in small threads traversing the quartzose veins of the more highly crystalline rocks; and (3) in grains and nodules in the soils partially filling up the valleys between hills of metamorphic rocks, and derived from them by degradation. It is most abundant in the first and third kinds of localities; and in the latter kind it is generally more abundant near the bottom of the drifts in the higher parts of the valley, than in the corresponding situations in the lowest parts of the valleys. In the first kind of locality it is usually accompanied by hæmatite, iron pyrites, and a few other sulphides; and in the drifts it has been frequently noticed that the most ferruginous are the most auriferous. All the schistose rocks contain gold, and generally those which contain most iron and manganese oxides are the richest in gold.

In Hungary and Mexico gold is associated with the

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sulphides of silver and copper; in the Sierra Coçaes of Brazil, with granular quartz and micaceous hematite; in Merionethshire with iron pyrites and decomposing blende; in the Harz it is found amongst decomposing iron pyrites; in California it occurs in grains, spangles, pepites, and nuggets, in alluvial soil, associated with hydrated peroxide of iron. Africa, Spain, Greece, Borneo, Sumatra, Cochin China, and Siam, also yield gold in considerable quantities. In Queen Elizabeth's reign upwards of £100,000 worth of the metal was obtained from Leadhills in Scotland; Cornwall also yields a little, and Wicklow has been at one time a gold field.

But the most important gold-bearing district is that of Australia, which, with North America, yields far more than all the other parts of the world put together. The principal districts in Australia are those to the west of Bathurst, but gold is found almost everywhere in the rocks of the great mountain ranges of New South Wales and Victoria, and in the alluvial deposits on their flanks. The gold producing area has been calculated to be not less than 16,000 square miles in extent.

Several native alloys of gold are known. The alloy of gold and silver is called an *electrum*, and varies considerably in its composition. Specimens from Siberia were analysed by Klaproth, and were found to contain 64 per cent. gold and 36 per cent. silver, corresponding to the formula Au. Ag.; but the proportion varies from 1 to 9 parts of gold to 1 of silver. The alloy has been found in Columbia, the Ural Mountains, and Brazil. A gold amalgam forms small white globules, accompanying platinum, in Columbia and California. An alloy of gold and palladium has been found at Gongo Socco, in Brazil, containing 25 per cent. of palladium; while another variety, containing 86 per cent. of gold, and 10 of palladium, has also been found in Brazil. The latter has received the name of *Porpezite*. Lastly, there is an alloy of gold and rhodium found in the platiniferous sand of Choco and Barbaçoa, New Granada, and also in Mexico.

PLATINUM. (Pt. Atomic weight, 197·4. *Syn.* Platina.)

With the exception of osmium and iridium this metal is the heaviest or densest substance known. It is usually associated with one or more of the heavier elements, such as palladium, iridium, rhodium, copper, and iron. It has a pale grey colour, and is usually found in round or flattened grains, less than a pea in size, and having a metallic lustre. Its sp. gr. varies from about 17 (190,026) in the less pure specimens to about 19·5 (217,971) in those which have been purified; and it may be raised to 21·5 (239,327) by hammering. When pure it resembles silver in colour, but as usually met with it is more or less grey; when pure it is rather softer than silver, and rather harder than copper; but its hardness is much increased when a little iridium is alloyed with it. It is exceedingly ductile and malleable, and is not inferior to iron in tenacity. At high temperatures it can be welded with great facility. Its conducting power for heat and electricity is high, but less than that of silver or gold. It is with difficulty fused at the highest temperatures which man can command, and when liquid absorbs oxygen, which it evolves again on solidifying. When a large quantity is suddenly cooled, it spits in the same way as silver. When in a very porous condition, as in the feebly coherent mass called *platinum sponge*, or in the impalpable powder called *platinum black*, it absorbs and condenses gases within its pores, and in some scarcely understood way heightens their chemical affinity.

Its unalterability by heat, oxygen, all acids but aqua regia, and by most chemical agents, renders it much sought for in the construction of crucibles, stills, evaporating dishes, &c. It is attacked by caustic alkalies and alkaline earths at temperatures above a red heat, as also by sulphur, phosphorus, arsenic, chlorine, and by charcoal in the presence of silica. It forms alloys with most metals.

Platinum occurs native in perfect octahedrons and cubes. It is not known when platinum was discovered, but Ulloa, who travelled in America in 1735, was the first to draw

general attention to the metal. It was originally found in the sands of Choco and Barbaçoa, in South America, and afterwards in Brazil and other countries. In 1822 it was discovered on the eastern side of the Ural Mountains, and this district is the source of the larger proportion of the platinum used in commerce, as well as of the most remarkable specimens in point of size and weight: one of these, in the Demidoff cabinet, weighs 21 lbs. troy, another 11½ lbs. It has also been found in Brazil, Borneo, in numerous parts of the U. States, Birmah, in California, Canada, the auriferous sands of the Rhine, and in some of the mineral veins of the French Alps. It is usually associated with gold and diamonds in alluvial deposits, and when found in its native beds (which are usually situated in a quartzose rock, much resembling a sandstone, and known as *itacolumite*), it is also accompanied by diamonds and gold.

Iridosmine. (Newjanskite · Sisserskite.)

Iridium itself is not known in a native state, but it occurs in conjunction with osmium, forming the alloy known as iridosmine. It occurs in many platinum ores, and sometimes forms the greater proportion of them, as in the case of those brought from Katharinenberg, Slatoust, and other places in Siberia. It generally forms hard, heavy, rounded grains, but sometimes it exists in the form of hexagonal prisms. It possesses a metallic lustre, a steel grey or tin white colour, and slight malleability; its sp. gr. varies from 19·3 (215,725) to 21·12 (236,079). These variations in colour and density result from variations in the proportions of the two metals. The variety which contains most osmium is steel-grey, and has the higher sp. gr.—viz., 21·1. Haidinger called it *Sisserskite.* Another variety consists of equal atomic proportions of iridium and osmium (Ir. = 47; Os. = 49, with a little rhodium and iron), and is tin-white in colour, while the sp. gr. is 19·5. Haidinger named it *Newjanskite.*

Maldonite.

A native alloy of gold and bismuth, having the composition $Au_2 Bi$. The hardness is 1·5 to 2; the sp. gr. between 8 and 10. Colour pinkish white. It is malleable, and easily fusible by the blowpipe. It was found in small particles in the quartz of the nuggety reef at Maldon, in Victoria.

Iron.

Native iron has lately been reported from numerous fresh localities, and under such circumstances as to narrow the distinctive marks assigned to meteoric irons. Thus the large blocks and small pieces found at Ovifak, in Greenland, are considered to be terrestrial, although they show the Widmannstätten figures in all. Thin laminæ have been observed in ironstone conglomerate of Brazil, in the lava of Auvergne, and in the Keuper sandstone of Thuringia. Metallic grains have been met with in pulverized basalts; and similar grains protected by a coating of magnetite have occurred in the mica schist of Scotland. Bahr reports grains in petrified wood, which are supposed to have been reduced from some iron mineral by the deoxidizing action of organic matter.

Platiniridium.

Small grains containing variable proportions of platinum and iridium have been found in Siberia, Ava, Brazil, and California. Sometimes they occur in cubes with truncated angles, with hardness of 6 to 7, and sp. gr. of 22·6. The platinum vessels used by chemists are usually alloyed with iridium, and the new standard metre measures consist of a platiniridium alloy.

CHAPTER IV.

ARSENIDES, SULPHIDES, TELLURIDES, AND SELENIDES; SIMPLE AND COMPOUND.

THERE are three arsenides of copper, which differ from one another in their proportion of copper. In *Domeykite* there are three atoms of copper, in *Algodonite* there are six, and in *Whitneyite* there are nine atoms. They all occur either in amorphous or semi-crystalline shapes, and possess many properties in common.

DOMEYKITE. (Cu_3As=Cu 71·7 and As 28·3.)

It occurs in reniform, botryoidal masses, and in a disseminated state, and is usually of a tin-white colour, slightly tarnished with a yellow or an iridescent coating. It breaks with an uneven, conchoidal fracture, and easily melts before the blow-pipe, which drives off the arsenic in fumes having the characteristic garlic odour of that element. Its hardness ranges from 3 to 3·5, and it has a metallic lustre. It is associated with red copper and arseniate of copper, in veins traversing porphyritic rocks at Calabazo, in Coquimbo, Chili, and also in argentiferous veins at San Antonio, near Copiapo, where it is intimately associated with Phillipsite, and accompanies limestone, native copper and silver, polybasite, &c.

Condurrite is generally considered to be domeykite in a more or less decomposed state, since scarcely any two specimens yield the same results when analysed. It is of a brownish-black colour, has a dull lustre, a metallic streak, and a specific gravity of from 4·2 (46,947) to 5·2 (58,125). It appears to consist of an arsenide of copper resembling domeykite, and of hydrated arsenite of copper mixed with a little manganese, sulphur, and silica. It is found in the clayey parts of the veins in the Condurrow and Huel Druid mines, Cornwall, and also in Chili. Insoluble in hydrochloric acid.

ALGODONITE. (Cu_6As=Cu 83·5; As 16·5.)

The purest specimens are fine-grained, brittle, of a steel-grey colour, and readily tarnish in the air. The fracture is sub-conchoidal, and the sp. gr. 7·603 (84,906). According to Genth, it is derived from *Whitneyite* by alteration. It was found in the silver mines of Algodones, near Coquimbo, Chili.

WHITNEYITE. (Cu_9As=Cu 88·2; As 11·8. *Syn.* Darwinite.)

It is finely granular, of a reddish or greyish white colour, and has no lustre on the fractured surfaces; but a scratch develops a highly metallic lustre, which, however, soon tarnishes. Its specific gravity varies from 8·2 (91,659) to 8·4 (93,895), and its fracture is subconchoidal. It is slightly malleable. It has been found in the Lake Superior district, and California, N. America.

ANTIMONIAL SILVER. (*Syn.* Dyscrasite.)

Although this occurs in a definite crystalline form, viz. in six-sided prisms with truncated lateral edges, and in scalenohedrons, yet it may eventually prove to be simply a solution of one metal in another. It retains some of the properties of a metal, as shown by its metallic lustre, its malleability, which, however, is very slight, and its colour, which differs very little from that of silver. Its specific gravity varies from 9·4 (105,073) to 9·8 (109,544), and its hardness from 3·5 to 4. This specific gravity is the same as is obtained by calculation, on the assumption that the specimens are simple mixtures. Thus, Klaproth analysed two specimens: one contained 24 parts by weight of antimony, and 76 parts of silver; the other, 16 parts of antimony and 84 parts of silver. A mixture of these metals in these proportions would have a specific gravity of 9·5 in the first case, and 9·8 in the second. When subjected to the blow-pipe, the antimony is driven off in fumes, and a globule is left which further heating reduces to silver. Nitric acid dissolves out the silver and oxidises the antimony, which remains insoluble. It tarnishes in

air to a yellowish-white or blackish-grey colour, and readily breaks with an uneven fracture. It is met with in certain argentiferous veins, especially those containing arsenical and antimonial minerals, at Andreasberg, Wolfach, Wittichen, Allemont, Guadalcanal, Casalla in Europe, and at Coquimbo in S. America.

The antimony is sometimes partially replaced by arsenic, which may form as much as 35 per cent. of the mineral. It is then called *arsenical silver*.

BREITHAUPTITE. (Ni Sb=Ni 31·9; Sb 68·7. *Syn.* Antimonial Nickel.)

It occurs in thin hexagonal plates, truncated on the basal edges, and striated on the basal faces, as also in dendritic masses and disseminated particles. It has a metallic lustre, an uneven fracture which presents a light copper colour with a tinge of violet, a reddish-brown powder and streak, a specific gravity of 7·54 (84,282), and a hardness of 5·5. When ignited in a tube the antimony is sublimated. It is slightly acted upon by simple acids, but readily dissolves in aqua regia. A vein of it was formerly worked at Andreasberg, where it was associated with calcspar, galena, and smaltine. It may be formed artificially, and indeed frequently occurs in the products of blast-furnaces. It is said to exist near the Pic du Midi d'Ossau, in the Pyrenees.

NICKELINE. (Ni As=Ni 44; As 56. *Syn.* Copper Nickel; Kupfer-Nickel; Arsenical Nickel.)

It is found native, crystallised in hexagonal prisms very similar to those of Breithauptite. The crystals are rare, and it generally occurs in reniform, reticulated, or arborescent clusters. The lustre is metallic, the fracture uneven and conchoidal, the colour copper-red, which changes to grey or black by tarnishing; the powder and streak are pale blackish-brown, the sp. gr. 7·5 (83,835), and the hardness 5·5. Before the blow-pipe, the arsenic is driven off in fumes, and the remainder melts to a white globule, which soon darkens. It is soluble in aqua regia

and nitric acid. The latter forms a green solution, which is turned violet-blue by ammonia. The nickel may be partially replaced by cobalt, and the arsenic by antimony, and sometimes by sulphur. It is frequently associated with the arseniate of nickel, which forms a pulverulent green coating over it, and accompanies cobalt, silver, copper, the sulphides of these metals, and smaltine. It has been found in various parts of Germany, Norway, France, Spain, at Chatham in Connecticut, at Leadhills in Scotland, and in the Fowey, Consols, and other mines of Cornwall. Exceedingly pure specimens have been obtained from St. Austell.

Nickel is largely used in the preparation of *German silver, nickel silver, packfong,* and *white copper.* These are alloys of copper, nickel, and zinc, in which the proportion of each metal varies according to the purpose for which the alloy is intended. Spoons and forks are formed of alloys of two parts copper, one nickel, and one zinc, or of eight parts copper, three nickel, and five zinc. Generally, the copper forms by far the largest proportion; but in the packfong of the Chinese there is almost as much nickel as copper.

LÖLINGITE. ($FeAs_2$=Fe 27·2; As 72·8. *Syn.* Leucopyrite.)

This mineral has considerable resemblance to mispickel both in form and atomic composition. Its crystals belong to the trimetric system, and usually occur as right rhombic prisms with an angle of 122°. They possess a perfect cleavage and a plane parallel to the principal axis. It has a metallic lustre, an uneven fracture, a slightly yellowish-silvery white colour, a specific gravity of 7—7·4 (82,717), and a hardness of 5·5. Both powder and streak are greyish-black. When heated with the blow-pipe it gives a slight odour of garlic, and yields a globule which is slightly magnetic. On treating the globule with nitric acid, arsenious acid is evolved, and the remainder dissolved. It is associated with copper-nickel at Schladming, Styria; with serpentine at Reichenstein, Silesia; with

bismuth and scorodite at Löling, Carinthia; and with native arsenic, antimonial silver, and red silver, at Andreasberg, Harz. It has been found in other parts of Germany, in Norway, and in the United States.

RAMMELSBERGITE. ($NiAs_2$=Ni 27·9; As 72·1.)

It closely resembles Lölingite in its crystalline form (which is a trimetric prism, having an angle of 123° to 124°), in its lustre, its streak, and in its fracture. Its colour is tin-white, with a slight reddish tinge in the fresh fracture; in massive specimens the colour inclines to steel-grey. Before the blow-pipe it behaves like nickeline. It is slightly ductile. Its specific gravity ranges from 6·4 (71,539) to 7·2 (80,481), and the hardness from 5·25 to 6. It is most usually met with in an amorphous or disseminated condition.

CLOANTHITE. ($NiAs_2$. *Syn.* White Nickel.)

Chemically, this is identical with Rammelsbergite, but its physical structure is different, since its crystals are cubes, octahedrons, and other forms belonging to the monometric system. Several minerals resemble it in form, and have an isomorphous composition, which may be expressed by the general formula $R_m As_n$, the R representing nickel, cobalt, or iron, which replace each other without altering the form of the crystal. *Chathamite*, from Connecticut, is a cloanthite in which a portion of the nickel has been replaced by iron. The specific gravity of cloanthite is about 5·6 (62,596). When heated in a closed tube arsenic is driven off, and it becomes converted into copper nickel, at the same time assuming the coppery red colour of that mineral. It is found in most of the localities where nickeline occurs, and, like it, is often covered with a green coating of arseniate of nickel.

KANEITE. (Mn As =Mn 42·3; As 57·7. *Syn.* Arsenical Manganese.)

This is very rare, and but little is known as to its characters. It occurs in botryoidal and amorphous masses, having

a granular structure. It is hard, of a greyish-white colour, and has a sp. gr. of 5·5 (61,479). In the air it changes, superficially, into a blackish-grey powder. It burns with a blue flame when heated by the blow-pipe, emits an odour of garlic, and yields white fumes of arsenious acid. It is quite soluble in nitro-muriatic acid, and nearly so in nitric acid.

SMALTINE. (Co As_2 = Co 27·7; As 71·3. *Syn.* Arsenical Cobalt; Grey Cobalt.)

Its crystals belong to the monometric system, and occur chiefly as cubes, octahedrons, dodecahedrons, and intermediate forms. The octahedral cleavage is distinct, but the cubic cleavage is indistinct. It is also found in massive, reticulated, and imitative shapes. The lustre is metallic, but readily becomes tarnished and blackened on exposure to the air. The colour is tin-white, inclining to steel-grey, or silver-white; the greyish tint belongs to the varieties which have a high specific gravity and contain a large proportion of iron. The streak is greyish black; the sp. gr. is 6·3 (70,411)—6·6 (73,774) (but some authorities state it to be as high as 7·7, probably based on specimens containing large amounts of impurity), and the hardness 5·5. When heated in a tube open at both ends it gives off a sublimate of arsenious acid; but no sublimate is formed in a test-tube. It dissolves in nitric acid, leaving a residue of arsenious acid. Smaltine is sometimes altered by atmospheric influences into cobalt bloom. The varieties which contain a large proportion of iron are called *Safflorite*. Smaltine is especially met with in veins of sulphide of silver and copper pyrites, particularly such as are developed in the more highly crystalline rocks, such as granites and gneiss. It is also accompanied by certain products derived from its decomposition, such as earthy arseniate of cobalt and black oxide of cobalt; also by other minerals, such as nickeline, native bismuth, native arsenic, galena, sulphide of silver. The stony minerals which usually form its gangue are sulphate of baryta, spathic limestone, dolomite, spathic iron, hyaline quartz,

and a few others. It is found in various parts of Germany, France, and Norway.

SKUTTERUDITE. ($Co\ As_3 = Co\ 20{\cdot}8$; As 79·2. *Syn.* Modumite.)

It is closely allied to smaltine; it resembles it in its crystalline forms; but the crystals present this difference, that in skutterudite the cubic cleavage is distinct, and the octahedral indistinct, which is the reverse of what is met with in smaltine. The sp. gr. is 6·74 (75,339)—6·84 (76,457), and the hardness 6; in both cases a little higher than in smaltine. The lustre and colour are the same, but skutterudite sometimes becomes iridescent. When heated in a closed tube it gives off a sublimate of arsenic. It is found with grey cobalt in a mineral vein traversing mica schist at Skutterud, in Norway.

HESSITE. ($Ag_2\ Te$ or Ag 62·77; Te 37·23. *Syn.* Telluric Silver.)

Its crystalline form has not been clearly ascertained. According to Rose it is a cube; but other observers say it is a rhombohedron so closely approaching a cube as not to be readily distinguished from it. There are no indications of cleavage. The sp. gr. is 8·5 (95,013) to 8·7 (97,248), and the hardness 3 or 3·5. It is ductile, but rather less so than sulphide of silver (argentite). The lustre is metallic; and the colour intermediate between lead-grey and steel-grey, but in some varieties it passes into iron-black. It melts before the blow-pipe, the tellurium is driven off, and the silver remains in a dendritic form. When heated in an open tube it gives a white sublimate of white telluric oxide. It is soluble in nitric acid. It occurs in small granular masses in a greyish green talc schist along with telluride of lead, chalcopyrite, pyrites, and blende, in the Savodinsky mines, Altai mountains, and in the Kolywan mines, Siberia. It also occurs in grey quartz, or in a porphyry diorite with diallogite at Nagyag, in Transylvania. *Petzite* is a variety with 25 p. c. of gold.

NAUMANNITE. (Ag_2Se or Ag 73; Se 27.)

Its crystals belong to the regular system, and present distinct cleavages parallel to the faces of the cube. It generally occurs as granular masses of an iron-black colour, and a bright lustre on the surfaces of the lamellar fractures. The sp. gr. is 8 (89,424), and the hardness 2·5. It much resembles sulphide of silver (argentite), but may be distinguished from it by its smaller ductility and its more perfect cleavages. When heated in a matrass it melts and gives off a sublimate of selenium and selenious acid. It is found in veins traversing diorite in the mines of Tilkerode, in the Harz, where it is accompanied by and intermingled with selenide of lead.

CLAUSTHALITE. (Pb Se or Pb 72·7; Se 27·3.)

This mineral much resembles galena, and indeed was confounded with it before the discovery of selenium. It occurs in fine granular masses which sometimes present traces of cubic cleavage. The lustre is metallic; the colour lead-grey, and sometimes bluish; the sp. gr. 7 (78,246) to 8·8 (98,366); and the hardness 2·5 to 3. It is readily cut by a knife. Before the blow-pipe it emits the horseradish smelling fumes of selenium, and if heated in the reduction flame, the lead is separated in the metallic form; when heated in a tube a sublimate of selenium is formed. In some specimens a part of the lead has been replaced by an equivalent proportion of silver or mercury. Nitric acid dissolves it. It is found in the Harz in threads traversing primary strata in the neighbourhood of dioritic rocks, and is sometimes accompanied by gold and palladium. The cupreous and cobaltic varieties are regarded as distinct species under the names *Tilkerodite* and *Zorgite*.

ALTAITE. (Pb Te = Pb 61·64; Te 38·36.)

This resembles clausthalite. It occurs in granular compact masses, which do not present any more definite structure than is afforded by its indistinct cleavages in

three directions at right angles to each other, from which it may be inferred that the cube is the primary form. The lustre is metallic; the colour tin-white, with a slight yellow tinge; the sp. gr. 8.16 (91,212); and the hardness 3—3·5. It is soft and sectile, colours the blow-pipe flame blue, and is fusible in the reduction flame. When heated in an open tube a sublimate of telluric oxide is formed. It is soluble in nitric acid. It is found in small quantities, associated with argentiferous tellurium and iron pyrites in talc schist at the mine of Savodinsky in the Altai mountains, Siberia.

ARGENTITE. (Ag_2S=Ag 87; S 13. *Syn.* Silver Glance; Vitreous Silver; Argyrose.)

It occurs in many varieties of form, viz., earthy, amorphous, mammillated, dendritic, and crystallised. The crystals belong to the monometric or cubic system, and consist of cubes, regular octahedrons, trapezohedrons, and combinations of these simple forms. There are traces of cleavage parallel to the faces of the cube and of the rhombododecahedron. The lustre is metallic; the colour dark steel-grey, but sometimes bluish-black, and iridescent when tarnished; the sp. gr. 6·9 (77,128) to 7·4 (82,722), and the hardness 2. It is soft, ductile, and sectile, and soluble in nitric acid, from which solution silver is precipitated when a piece of copper is introduced into it. When exposed to the blow-pipe flame the sulphur is driven off, and the silver remains behind as a brilliant globule. It is met with in veins traversing gneiss, mica schist, hornblende rock, argillaceous schist, granite, porphyry, and trachyte; and the minerals which accompany it are native silver, pyrargyrite, argentiferous galena, arsenic, hyaline quartz, calcspar, barytine, fluorspar, and a few others. There are a great many localities in Germany, Bohemia, Hungary, Norway, Mexico, Peru and Chili, but the principal veins are those in the silver mines of Saxony and Bohemia, and in the silver mines of Potosi.

Akanthite has the same composition and properties as

argentite, but it crystallises in long needles belonging to the trimetric system.

BLENDE. ZnS = Zn 66·72; S 33·28. *Syn.* Black Jack; Sphalerite.)

Although this mineral occurs in cubes and octahedrons like most of the minerals already mentioned in this chapter, there is an important difference to be noticed, inasmuch as the cube is not modified in the same way. In the ordinary cube all the edges and angles are similarly modified, but in the cube of blende only half the edges and angles are modified. The consequence is that these derived forms have only half the number of faces, &c., which we find in the corresponding forms derived from the ordinary cube; hence these are called *hemihedral.* The principal crystalline forms are the tetrahedron, rhomboidal dodecahedron, and the octahedron. Its colour varies considerably; in the purest specimens it is yellowish-green, but when mixed with other sulphides it presents various shades of red, brown and black; and when a large proportion of iron is present it may be deep black. The translucency also varies, being greatest in the purest varieties, and least in the dark ones. The crystals, both externally and when fractured, have considerable brilliancy, but very little metallic lustre; in specimens that are not cleavable the fracture is often waxy. It is soft, having a hardness of 3·5; and one of the lightest of the sulphides having a sp. gr. of 3·9 (43,494)—4·2 (46,947) only. Its sp. ht. is ·120. The purer specimens are remarkable for the facility with which they can be rendered phosphorescent by friction. It can be fused with difficulty by the blow-pipe, and is only slightly soluble in nitric acid. The varieties of form and structure presented by blende are too numerous to be even mentioned, but the principal are the laminar, radiated, and concretionary varieties. Blende is found almost everywhere, and in nearly all the geological formations; but most abundantly in the veins of galena, iron and copper pyrites, grey copper, and more especially in those which contain lead. Galena

and blende have a close resemblance to each other, and frequently occur together. Blende does not occur abundantly in the more highly crystalline rocks, such as gneiss, mica schist, talc schist; but it is exceedingly abundant in rocks not so highly crystalline, such as argillaceous schists, certain limestones, &c. It occurs in greater or less quantity in the various sedimentary rocks older than the muschelkalk of the permian series, but it is seldom found except in a disseminated state in rocks newer than that mentioned.

GALENA. (PbS = Pb 86·6; S 13·4.)

Its crystals belong to the regular or monometric system, and are either cubes or some of the simpler derivations therefrom. The commonest form is the cube, and this is intimately connected with its remarkably easy cubic cleavage. There is also an easy octahedral cleavage, but it is generally difficult to obtain on account of the cubic cleavage being far easier. Sometimes, but rarely, a variety is found in which the octahedral cleavage is the most marked, as in some crystals from Lebanon and Pennsylvania. The most common combination form is the cube-octahedron (Figs 2, 4, Pl. I.). Galena has a metallic bluish-grey colour, a hardness of 2·5, a sp. gr. of from 7·4 (82,717) to 7·6 (84,952), and a sp. ht. of ·049. It is easily fusible, the sulphur being given off in fumes of sulphurous acid, and the oxide of lead remaining on the charcoal support as a yellowish film which on further heating yields a globule of lead.

The lead is sometimes partially replaced by equivalent proportions of silver, copper, antimony, bismuth, iron and platinum, giving rise to the argentiferous, cupreous, antimoniferous, bismuthiferous, ferriferous, and platiniferous varieties of galena. Galena is the most important of the lead ores, and occurs in considerable masses. Most of the workable lead veins are situated in the primary rocks; a few exist in the secondary, but they are comparatively rare above the lias. The most common gangues of galena are limestone, quartz, barytine, fluor-

spar, &c. The principal lead mines in France are at Poullaouen and Huelgoat near Carhaix, in the department of Finisterre; those of England are mostly situated in Derbyshire, Cumberland, and Cornwall. Galena is also found abundantly in many other parts of Europe, in Siberia, in Algeria, in South Africa, in Australia, and in North America. The galena deposits of Iowa are exceedingly interesting to the mineralogist. *Steinmannite* is probably an impure variety.

ALABANDITE. (Mn. S = Mn 63·23; S 36·77. *Syn.* Manganese blende.)

It is rarely met with in the crystallised form, such as cubes and regular octahedrons with perfect cubic cleavage. It is more usually found in masses which are granular in structure, and which readily cleave in three directions apparently parallel to the faces of the cube. The lustre is sub-metallic, the colour iron-black when fresh, and brown when tarnished, that of the streak being green: the sp. gr. 3·9 (43,494)—4·81 (53,766), and the hardness 3·5—4. Iron-black rhombic prisms of alabandite have been formed by artificial crystallisation, and others in the form of octahedrons have been met with as a furnace product. The latter differed from the natural crystals in being attracted by the magnet. It is soluble in hydrochloric and nitric acids. It has been found at Kapnik and Nagyag, Transylvania; Gersdorf, Saxony; Alabanda, Caria; and in Mexico.

STROMEYERITE.

No formula can be assigned to this mineral, since it appears to be a mixture of sulphide of silver with sulphide of copper. Generally speaking, these two sulphides crystallise in two distinct crystalline systems, but under certain circumstances each sulphide will crystallise in both systems, and in similar forms. The crystals which contain most sulphide of silver are in cubes and octahedrons like argentite. This is the case with the specimens from Jalpa, in Mexico, which Breithaupt calls

Jalpaite. They contain Ag 71·76; Cu 14·02; S 14·22. Other crystals have been found at Rudelstadt, in Silesia, and one or two other places, having the form of six-sided trimetric crystals.

COPPER GLANCE. (Cu_2 S or Cu = 79·73; S = 20·27. *Syn.* Vitreous Copper Ore; Redruthite; Harrisite; Chalkosine.)

The crystals occur in six-sided tables, which were formerly considered to be regular hexagons; precise measurement, however, has shown that they are not quite regular, and that they belong to the trimetric, not to the hexagonal system. It is often intimately mixed with sulphide of silver, and then such crystals assume forms belonging to the regular system. It also occurs massive, with a granular compact structure. Its colour is steel-grey; its fracture conchoidal, unequal, and with a metallic lustre, which is not quite so brilliant as in argentite. Its sp. gr. is 5·5 (61,479) to 5·8 (64,832) in native, but as much as 5·97 in artificially prepared, crystals; its hardness 2·5—3; and its sp. ht. ·120. It is brittle, and sufficiently soft to be cut with a sharp knife. It dissolves with difficulty in heated hydrochloric acid, with evolution of sulphuretted hydrogen; and when dissolved in nitric acid the sulphur is separated; this latter solution is turned blue by an excess of ammonia, and precipates copper on steel. Copper glance is met with in veins of copper pyrites in Cornwall, Hesse, Mansfeld, the Bannat; but it is more abundant in Siberia, where it is extensively sought for by mining. In Siberia copper pyrites still accompany it, but in comparatively small quantities. The fine crystals at Redruth, Cornwall, are called *Redruthite.* Copper pyrites, purple copper, and black copper occur as pseudomorphs after copper glance; while the latter is itself pseudomorphous after galena. This last pseudomorph has been found in the Canton mine, Georgia, and has been named *Harrisite.*

GREENOCKITE. (CdS or Cd = 77·8; S = 22·2.)

Sulphide of cadmium, or Greenockite, is a rare mineral,

which crystallises in double six-sided pyramids belonging to the hexagonal system, and having a cleavage parallel to the edges of an hexagonal prism. The crystals are of a semi-transparent, honey yellow colour, but its powder is orange yellow or brick red. When heated the crystals become first brown and then carmine-red, but resume their lemon yellow tint when cooled. These changes in colour are similar to those undergone by sulphur under similar circumstances. The sp. gr. is 4·8 or 4·9 (54,772), and the hardness 3·5. It readily dissolves in strong hydrochloric acid when heated, and gives off abundance of sulphuretted hydrogen; it also dissolves in nitric acid, the solution being attended by evolution of sulphuretted hydrogen, and deposition of sulphur. It is found in small crystals in an amygdaloidal trap, near Bishoptown, in Renfrewshire, where it is accompanied by prehnite, felspar, and galena.

MILLERITE. (NiS or Ni = 64·76; S = 35·24. *Syn.* Capillary Nickel.)

It occurs in rhombohedral crystals having an angle of 144·8°, with the principal axis = ·329, and with a perfect cleavage parallel to the faces of the rhombohedron; but more frequently in long, slightly elastic needles, having the crystalline form of hexagonal prisms. Specimens are said to have been found in which only half the faces were developed, and which would consequently be trigonal prisms. This mineral is brittle, has a sp. gr. of 5·25 (58,684)—5·65 (63,155); a hardness of 3—3·5; a sp. ht. of ·128; a brass yellow colour; a metallic lustre; and dissolves wholly in aqua regia, yielding a greenish solution, but partially in nitric acid, yielding a pale green solution, which is rendered violet by the addition of ammonia. It has been found in various parts of Germany, England, and America, and is usually accompanied by one or more of the following minerals—viz., quartz, calcareous spar, carbonate of iron, and various ores of nickel, cobalt, lead, and silver.

CINNABAR. (HgS or Hg = 86·29; S = 13·71.)

It usually occurs in minute crystals belonging to the hexagonal system, and derivable from an acute rhombohedron of 71° 48′, the length of whose principal axis is 2·29. The cleavage parallel to the edges of the hexagonal prism is well marked, but not so that which is parallel to the faces of the rhombohedron. The crystals are transparent or translucent, and of a fine carmine colour; but certain faces have a steel-grey aspect when viewed by reflected light. The lustre is adamantine; the sp. gr. varies from 8 (89,424) to 8·2 (91,659); the sp. ht. ·0517; and the hardness from 2 to 2·5. When pure it is slightly ductile, and soft enough to be easily cut with a knife. It sometimes occurs massive, with a granular structure, a colour inclining to steel-grey, and a slightly metallic lustre; and sometimes as a fine scarlet powder (native vermilion), filling cavities in the massive cinnabar. There is also an impure variety, with a slaty structure, and of a dark liver red or blackish colour, which contains earthy matter, carbon, and sometimes bitumen. It is called *hepatic ore*, and is the principal ore worked in the mines at Idria, in Carniola. Cinnabar is a bad conductor of electricity, and when rubbed and insulated, it is charged with negative electricity. It is doubly refractive, and in this and several other respects it much resembles quartz in its optical properties. When heated on charcoal before the blowpipe, it is entirely volatilised, yielding mercury vapour and sulphurous acid. It is entirely soluble in aqua regia, but is insoluble both in nitric and in hydrochloric acid. When a copper blade is placed in a solution of cinnabar, or is held in its vapour, it is whitened by the deposition of the mercury. It is readily distinguished from all other transparent minerals by its high specific gravity, and from the three common red minerals by its vermilion powder, which is orange yellow in realgar; by its odour when heated, which is that of sulphurous acid in cinnabar, but alliaceous in realgar; by its complete volatility, which distinguishes it from red silver, which yields a button of silver, and from red lead,

which leaves an aurora coloured powdery residue. Rutile also has a red colour, but it possesses only half the specific gravity of cinnabar, and is not at all altered by the blow-pipe. Like sulphur and greenockite, cinnabar undergoes changes of colour when heated; thus it is brownish when gently heated, quite brown at 482° F., and black at a higher temperature. If cooled without being volatilised, it regains its vermilion colour. Cinnabar is found in veins, in the older palæozoic crystalline schists, and disseminated in the grits, bituminous schists, and compact limestones of the lower part of the secondary rocks. The latter mode of occurrence occurs in the greater number of localities where cinnabar is found, but the yield is scarcely ever so rich as in the older crystalline schists. The principal European mines are at Idria in Carniola, and in Rhenish Bavaria. At the former locality it occurs in fossiliferous limestones and schists, but more abundantly in the schists. The shells and the fish scales in them are frequently metamorphosed into sulphide of mercury. The great mining centres in Europe are Almaden in Spain, Idria, Moschel-Landsberg, and Ripa. At Almaden it is found in veins sometimes as much as 50 ft. thick, traversing micaceous schists. Mines also occur in the Ural and Altai mountains, Siberia, in Thibet, China, Japan; at Huanca Velica, in Peru, at Guallilinga in Chili, in Mexico, and in California. The mines in the last country have proved to be remarkably rich; they are named New Almaden and Guadeloupe, and the ore occurs as veins in crystalline schists. There are a great many other localities where cinnabar is found in quantities insufficient for mining purposes, but we cannot enumerate them here.

COVELLINE. (Cu S or Cu = 66·4; S=33·6. *Syn.* Indigo Copper; Blue Copper.)

This mineral was first discovered in small thin hexagonal plates, or a pulverulent powder, lining the interior of the cavities of lava in the fumaroles of Vesuvius, and forming a blackish network like a spider's web. The crystals at

Salzburg present the faces of two hexagonal pyramids combined with those of a regular hexagonal prism, and readily cleave in a direction parallel to the base. In the mass, this mineral has a deep indigo colour, but, when powdered, it is black. Its hardness is 1·5 or 2, its specific gravity is 4·6 (51,418), and it is readily reduced to a powder by rubbing it between the fingers. It is opaque, and has a lustre which is sometimes slightly metallic and in others resinous. It is soluble in nitric and hydrochloric acids, but in the latter acid the sulphur is separated. It is slightly soluble in sulphide of ammonium, but insoluble in aqueous sulphurous acid, potash, and the fixed alkaline sulphides. Besides the locality above mentioned, it is also found accompanying other ores of copper in bituminous schists, at Sangerhausen, Saxony; Mansfeld, Thuringia; Leogang, Saltzburg; Kielce, Poland; in the Harz, the Black Forest, and Chili. *Cantonite* is a pseudomorph of covelline after galena found in Georgia and in Cornwall.

EUKAIRITE. (Ag Cu Se or Ag = 43·16; Cu 25·26; Se = 31·58; a selenide of silver and copper.)

The crystalline form is unknown; but as *Naumannite*, the selenide of silver, belongs to the regular system, and as copper and silver are isomorphous, it is probable that eukairite crystallises in cubes, or some form derivable from the cube. It is found amorphous, and intimately associated with calcspar, in a magnesian serpentine rock in the abandoned mine of Skrikerum, near Smaland, Sweden. It is of a lead-grey colour, soft, and slightly ductile; it has a fine-grained fracture, and it gives a shining streak. Before the blowpipe the selenium is driven off in vapour, and a grey, shining, metallic globule is left: when treated with fluxes, it gives the reactions of copper. It is soluble in nitric acid, from which the copper and silver may be reprecipitated by means of iron.

BERZELIANITE. (Cu_2Se or Cu = 61·48; Se = 37·52. *Syn.* Berzeline.)

Its crystalline form is unknown, as it has hitherto been found only in thin dendritic crusts, having a silver white colour and a metallic lustre; and in thin veins in the copper mine of Skrikerum, near Smaland, and near Lehrbach, in the Harz.

ONOFRITE.

This name is given to a series of specimens whose composition varies considerably. It was first given to specimens found at St. Onofre, in Mexico, to which H. Rose assigned the formula Hg (S Se); and the composition of mercury, 81·33; sulphur, 10·30; and selenium, 6·49. It is, therefore, a sulpho-selenide of mercury, or, what seems more probable, an isomorphous mixture of sulphide and selenide of mercury. It occurs in granular compact masses, having no traces of cleavage, which are accompanied by quartz, calcspar, and barytine. This name is also given to certain grey and red minerals found at Calabria, in Mexico, and which contain variable proportions of sulphur, selenium, mercury, and zinc. These appear to be mixtures of several distinct minerals.

NAGYAGITE. (*Syn.* Elasmose; Foliated Tellurium; Black Tellurium; Tellurium Glance.)

The analyses of this mineral have yielded such different results, that no one formula will represent them. It is a native telluride of lead and gold, and crystallises in forms belonging to the dimetric system, which have the principal axis equal to 1·298. The cleavage parallel to the base is very distinct, and, consequently, it is usual to find it in lamellar masses. The hardness is 1 to 1·5; the sp. gr. 6·8 (76,010) to 7·2 (80,481); the colour and streak a dark lead-grey, and the lustre metallic. In thin laminæ it is slightly flexible. Heated in charcoal, with the blowpipe, it gives a blue tint to the flame (arising from sulphur)

and a yellow deposit, which, when reduced in the inner flame, yields a globule of gold. When treated with nitric acid a portion is dissolved, and what remains is sulphate of lead, containing gold; with aqua regia, the residue is sulphur and chloride of lead. In all specimens hitherto examined the tellurium has been partially replaced by sulphur, and, in most, antimony has been substituted for an equivalent of the lead. It is found at Nagyag and one or two other places in Transylvania, associated with sylvanite, red manganese, alabandine, bournonite, blende, arsenic, hyaline quartz, and native gold.

HAUERITE. (MnS_2 or Mn = 46·19; S = 53·81.)

A native bisulphide of manganese, which crystallises in cubes, octahedrons, and other simple forms belonging to the regular system. When powdered or in thin laminæ it has a brownish red colour resembling that of hausmannite; but in the massive state the colour is darker, and approaching to a blackish brown. It possesses a perfect cubic cleavage; a sp. gr. of 3·46 (38,609); a hardness of 4; a semi-metallic or adamantine lustre, and a moderate degree of translucency. When heated in an open tube it disengages sulphur, and leaves a green powder. As will be seen, it much resembles alabandite, from which it is distinguished by its chemical composition and its lower specific gravity. It has been found at Kalinka, in Hungary, in a clay formed from the decomposition of trachytes and diorites. It is associated with sulphur and gypsum.

IRON PYRITES. (FeS_2 or Fe = 46·67; S = 53·3. *Syn.* Martial Pyrites; Mundic; Cubic Pyrites.)

The bisulphide occurs native in two different forms, of which the most common is the cubic or yellow variety. Its crystals are cubes, octahedrons, and forms derivable from them by hemihedral modification. It is most frequently met with in cubes, which sometimes have

smooth faces, and sometimes striated faces. In the three faces which meet at the same solid angle, the striæ run in three different directions, as shown in Fig. 32. Next to the cube the pentagonal dodecahedron (Fig. 14, Pl. I.) is most common, while other forms are shown in Figs. 2, 10, 13, 16, and 18 of the same Plate. The colour is brass-yellow, sometimes gold-yellow, which passes into brown by superficial alteration; the powder and streak are brownish-black; the lustre is metallic; the sp. gr. is about 5 (55,890) in pure specimens, but ranges from 4 to 5, according to the degree of alteration they have undergone; the sp. ht. is ·123; the fracture is conchoidal, rather more so than in copper pyrites; and the hardness is 6 or 6·5, which is sufficient to enable it to strike fire with steel. This latter property was known to the ancients, who gave it its present name, which signifies *fire-stone*. When firearms were first introduced it was used for obtaining the spark, but was soon superseded by gun-flints, which have in their turn given way to percussion caps. Before the blow-pipe the sulphur is driven off, giving a bluish tint to the flame, and the magnetic oxide of iron remains behind. It is slightly soluble in sulphuric acid; while nitric acid takes up the iron and deposits the sulphur. It is much less easily altered by exposure to the atmosphere than marcasite, but is frequently changed into limonite or hydrated peroxide of iron. The iron is generally more or less replaced by cobalt, nickel, gold, silver, and copper. Yellow iron pyrites occur almost everywhere, but never in any large masses. It is found in veins, and disseminated through sedimentary and crystalline rocks of every geological age. It is deposited from many mineral waters, and appears to be formed whenever protoxides of iron, sulphates, organic substances, and water are intimately mingled together. It is seldom mined, except for the sake of the sulphur and gold it may contain. Its yellow colour has often caused it to be mistaken for gold by persons unacquainted with mineralogy.

Fig. 62.

MARCASITE. (FeS_2. *Syn.* White Iron Pyrites; Radiated Pyrites; Spear Pyrites; Cellular Pyrites.)

Although similar to the common iron pyrites, it crystallises in very different forms, such as the right rhombic prism (Fig. 30, Pl. II.), and derivative modifications belonging to the trimetric system. The cleavage is distinct in a direction parallel to the faces of the prism. Marcasite has considerable resemblance, in its crystalline forms, to arsenical pyrites, or mispickel, but is readily distinguished from it by its tendency to form rosette-like groups. The colour is pale bronze-yellow, sometimes inclining to green or metallic white, while that of the powder and streak is greyish-black. By alteration it becomes brownish or iridescent. The lustre is metallic; the sp. gr. 4·6 (51,418)—4·8 (53,654); the hardness 6 to 6·5; and the fracture uneven. It resembles the common pyrites in its behaviour before the blowpipe, but differs from it in its greater readiness to alter in moist air into the sulphate of iron. This oxidation is sometimes sufficiently intense to set up combustion in the lignite or coal in which it may be contained. It is often met with in radiated, dendritic, cellular, compact, reniform, and globular masses. It is less widely distributed than the cubic pyrites; but it is more or less disseminated through many schists, coal, lignite, peat, clays, marls, chalk, and sometimes flint. The finest crystals come from Cornwall, Derbyshire, Saxony, and Bohemia. The brown radiated nodules in chalk cliffs are marcasite, their colour being due to the formation of an external film of hydrated peroxide of iron. The high polish which marcasite takes, and its greater freedom from tarnishing than steel, led at one time to its being extensively used for ornaments. About twenty years ago the French and Swiss jewellers manufactured immense quantities into pins, bracelets, buckles, buttons, and other articles, and they still retain the great bulk of the trade, although it has fallen off very much of late years. The ancient Peruvians used polished masses of it for mirrors and ornaments. The masses

were far larger, and of a purer white, than can be found now, and it is usual to refer to them as a variety of marcasite under the name of *pierre des Incas*, or stone of the Incas, in allusion to its use having been almost entirely confined to the Incas, or ancient nobles of Peru.

MOLYBDENITE. (MoS_2, or Mo = 59·80; S = 40·20.)

There is some uncertainty to which system its crystals belong. Koksharow assigns them to the trimetric, or possibly to the monoclinic system, to which latter Nordenskiold and others also think they may belong. There is also an opinion among some mineralogists that they belong to the hexagonal system. The mineral has a pure lead-grey colour, and in hardness and external characters resembles graphite; but it is readily distinguished from it by the green trace it leaves on porcelain, and by its partial solubility in nitric acid. It is soft (H = 1 or 1·5), smooth to the touch, ductile, and slightly flexible in thin plates; the lustre is metallic; the sp. gr. 4·5 (50,301)—4·8 (53,654), and sp. ht. ·123. It is with difficulty fusible in the blowpipe flame; on charcoal the sulphur is driven off, while the molybdenum is oxidised, and forms a yellowish white incrustation of molybdic acid. On platinum the flame is coloured green. It occurs in many of the older crystallised rocks, such as granite, schist, or in metalliferous veins traversing them; it is only met with in small quantities, but has been found in numerous localities, and amongst others, Cornwall, Cumberland, Leicestershire, in England; Saxony, France, Norway, Sweden, Finland, Siberia, Greenland, United States, Brazil, &c. *Pateraite* is probably a sulphide of molybdenum. Its composition is said to be MoS_3; but hardly anything appears to be known as to its properties.

REALGAR. (AsS or As = 70; S = 30. *Syn.* Red Orpiment; Ruby Sulphur.)

It occurs in small granular masses and in crystals of an orange-yellow, or aurora red colour. The crystals are

more or less translucent, and have a resinous lustre, a conchoidal fracture, a specific gravity of from 3·4 (37,905) to 3·6 (40,140), a sp. ht. of ·111, and a hardness of 1·5 or 2, which is less than that of the finger nail, by which they are easily scratched; they consist of oblique rhombic prisms and belong to the monoclinic system. It is readily fused by the blowpipe, and may be volatilized by it into a yellowish or reddish vapour, which has a strong odour of sulphurous acid. This, together with its lower specific gravity, serves to distinguish it from the red ores of silver and lead.

It is usually found in volcanic rocks and in veins containing silver, lead, and cobalt ores. In the Hungarian localities it is accompanied by native arsenic, yellow orpiment, bismuth, and blende; in the Binnenthal, Switzerland, it forms small threads in granular dolomite accompanied by iron pyrites; at Falkenstein the gangue is granular gypsum, and the accompanying minerals are yellow orpiment and blende; it also occurs in beds of clay, as at Tajowa, Hungary, and in lavas, such as that which flowed from Vesuvius in 1794.

SYLVANITE. ($\overbrace{Au; Ag.}$ Te_3 or Au = 28·6; Ag = 15·6; Te = 55·8. *Syn.* Graphic Tellurium.)

It occurs in exceedingly minute prismatic acicular crystals, derivable from a right rhombic prism with an angle of about 108°. They are grouped together at angles of about 120° and 60°, so as to have some resemblance to the Persian writing. The specific gravity is 8·28 (92,553), according to Petz; the hardness 1·5 or 2; the fracture uneven; the lustre metallic; and the colour a clear steel-grey. When fused on charcoal it colours the flame green and leaves a yellow residue of gold and silver; in nitric acid the tellurium is dissolved and the gold and silver left as a yellow precipitate. In aqua regia the tellurium and gold are dissolved and the silver precipitated as chloride. It is found, associated with native gold and tellurium ores, in veins traversing porphyry at Offenbanya. A variety is met with at Nagyag, in which the silver has

been more or less replaced by lead and antimony, and the characters somewhat modified. It is called *müllerine*, and has a silvery white colour. The various specimens referred to sylvanite and mullerine, may be regarded as isomorphous mixtures of $AuTe_3$, $AgTe_3$, $PbTe_3$, $AuSb_3$, $AgSb_3$, and $PbSb_3$.

ANTIMONITE. (Sb_2S_3 or Sb = 72·77; S = 27·23. *Syn.* Stibnite; Stibine; Gray Antimony; Antimony Glance.)

It crystallises in six-sided prisms terminated by four-sided summits, which belong to the trimetric system. The cleavage is distinct, parallel to the shorter diagonal and principal axis. The faces of the prism are striated longitudinally, which indicates their readiness to break up into acicular and capillary crystals, the form the mineral usually assumes. The colour is lead-grey, inclining to steel-grey; the lustre metallic; the fracture subconchoidal; the specific gravity 4·5 (50,301)—4·6 (51,418); the sp. ht. ·090; and the hardness 2. The thin laminæ obtained by cleavage are slightly flexible. Antimonite is easily fusible, thin splinters melting even in a candle flame, while it is entirely vaporized by the blowpipe. It dissolves in hydrochloric acid, with disengagement of sulphurous acid; and in nitric acid it is converted by oxidation into sulphate of antimony. It is sometimes found altered by partial oxidation into *kermesite*, and by further oxidation into *valentinite*, or the white oxide of antimony. Although not very abundant, it is sometimes accumulated in sufficient quantities to be worked as an ore. It forms veins in the granitic and crystalline schists of Auvergne, Hungary, France, Bohemia, and other countries, and sometimes occurs in secondary rocks, as at the Perette mine, near Monte Cavallo, Tuscany. It is also met with in Cornwall, and has been brought from Borneo.

BISMUTHITE. (Bi_2S_3 or Bi = 81·5; S = 18·5. *Syn.* Bismuthine; Bismuth Glance.)

It crystallises in acicular prisms of the trimetric system,

similar in form to those of antimonite, and which, like them, have the faces of the prism striated in a longitudinal direction. The cleavage is distinct, parallel to the smaller diagonal and to the principal axis. The colour is lead-grey or steel-grey, the lustre metallic, the specific gravity 6·4 (71,539), to 6·5 (72,657), and the hardness 2 to 2·5. It is easily fusible, and when heated in the reducing flame of the blowpipe the sulphur is driven off, and a globule of bismuth is left. It is slowly dissolved by nitric acid. This mineral is rare, and, in addition to its crystalline state, is found in lamellar and fibrous masses in the primary rocks at Bastnas, Sweden, accompanied by copper pyrites; at Joachimsthal, Bohemia, associated with native bismuth; at Haddam, Connecticut, associated with chrysoberyl; also in Saxony, Cornwall, and Cumberland.

ORPIMENT. (As_2S_3 or As = 60·90; S = 39·10.)

The crystals are rhombic prisms belonging to the trimetric system, but on account of their rarity, and want of sharpness of outline, it is not certain whether they are or are not isomorphous with those of antimonite. They possess a distinct cleavage, parallel to the small diagonal, and split up into thin flexible laminæ; while the faces produced by this cleavage are striated longitudinally. They are translucent, of a lemon or bright orange-yellow colour, and have a pearly lustre on the cleavage faces, and a resinous one on the others. Their specific gravity is 3·4 (38,905), and sp. ht. ·113. Its chemical properties resemble those of realgar, but there is one difference, viz., that orpiment gives a yellow crystalline deposit when heated in a closed tube, while realgar gives a deposit of small red crystals. Orpiment occurs in the same geological situations as realgar, and frequently accompanies it. The orpiment of commerce is brought from the Levant, and is used for making a pigment. *Dimorphine* is an allied mineral which occurs as orange-yellow crystals in the Italian fumaroles.

COBALTINE. (Co As S or Co = 35·47; As = 45·18; S = 19·3. *Syn.* Cobalt Glance; Silver-white Cobalt; Sulpharsenide of Cobalt.)

It crystallises in the same forms as iron pyrites, such as the cube, octahedron, pentagonal dodecahedron, and hemihedral modifications of them as in iron pyrites. This last character distinguishes it from Smaltine, a mineral which is often confounded with it. There are other differences, such as that cobaltine is a sulpharsenide of cobalt, smaltine an arsenide of cobalt; cobaltine has a distinct cubic cleavage, while smaltine has an indistinct one; cobaltine has a tin or silver white colour with a roseate tinge, smaltine has the same colour with a greyish tinge; cobaltine has a specific gravity of 6·2—6·3 (70,411), smaltine of 6·3—6·6 (73,774), and we might mention several others. The hardness of cobaltine is 5·5, the sp. ht. ·107, the fracture uneven and imperfectly conchoidal, and the streak greyish black. On heating it in the blowpipe flame, it gives off arsenical and sulphurous fumes, and yields a dull black feebly magnetic globule, which, when melted with borax, imparts to it the intense blue flame so characteristic of cobalt and its ores.

With nitric acid it gives a violet solution, and a residue of arsenious acid. It is readily distinguished from iron pyrites by its greater specific gravity and its colour. In some specimens the cobalt is partially replaced by iron.

Cobaltine forms veins and lumps in gneiss associated with copper pyrites, common iron pyrites, marcasite, quartz, calcareous spar, hornblende, &c. Its principal localities are Tunaberg, Hakambo, Riddarhyttan, Sweden; Skutterud, Norway; Querbach, Silesia; Siegen, Westphalia; Connecticut, United States; and several places in Cornwall.

NICKEL-GLANCE. (Ni As S or Ni = 35·5; As = 45·16; S = 19·3. Gersdorffite; Sulpharsenide of Nickel.)

This mineral differs from the last in containing nickel in the place of cobalt, but resembles it in many of its properties. It crystallises in the same forms, has the same

hardness, and the same specific gravity. The colour is somewhat different, being a bright steel-grey approaching to silver white. It is partially soluble in nitric acid, giving a green solution with a residue of sulphur and arsenious acid; the green colour is changed to violet by the addition of a little ammonia. It has been found at Loos, Helsingland, Sweden, associated with cobalt ores; also in Styria, Hungary, various parts of Germany, and at Phœnixville, Pennsylvania, where it is associated with quartz, chalcopyrite, and covelline. The arsenic is replaced partially or even wholly by antimony; and thus the nickel-glance may become metamorphosed into ullmannite, the mineral next to be considered. The *Tombazite* of Breithaupt and *Amoibite* are probably varieties of nickel-glance.

ULLMANNITE. (Ni S Sb or Ni = 27·3; S = 15·0; Sb = 57·7. *Syn.* Grey Nickel; Sulphantimonide of Nickel.)

This mineral is analogous to cobaltine and nickel-glance in composition; but, although sulphur is the only common ingredient, all three are isomorphous. Its colour is steel-grey; hardness 5·5; and sp. gr. 6·4 (71,539). When heated in the test tube it gives off fumes of antimony and sulphurous acid, and a garlic odour. The latter is due to arsenic, which is usually present in small quantities. It is partially soluble in nitric acid, antimonious oxide being precipitated. The solution is green, and is rendered violet by the addition of ammonia. It is rarely found crystallised, but generally in lamellar or compact masses. It occurs associated with cobalt ores, galena, and copper pyrites, at Siegen, Prussia; at Westerwald, Gosenbach, and one or two places in the Harz.

MISPICKEL. (Fe As S or Fe = 33·57; As = 46·53; S = 19·90. *Syn.* Arsenical pyrites; Arseno-pyrite; Sulpharsenide of Iron.)

Like marcasite, it crystallises in right rhombic prisms belonging to the trimetric system, and possesses a distinct cleavage parallel to the faces of the prism. It most fre-

quently occurs in short prisms, or tables, or columns. Its colour is silver white, inclining to steel grey or yellowish; the powder and streak are dark greyish black; the lustre is metallic; the sp. gr. 6—6·4 (71,539); the sp. ht. ·101; the hardness 5·5—6; and the fracture granular and uneven. When heated in a tube the red sublimate of sulphide of arsenic is given off; and when heated by the blowpipe on charcoal the sulphur and arsenic are driven off, and a black magnetic globule of iron (sometimes containing cobalt) remains. In hydrochloric acid the iron and arsenic are dissolved, and the sulphur separated. It is most easily distinguished from marcasite by its hardness and specific gravity. The iron is sometimes replaced by cobalt, giving rise to the cobaltiferous varieties, and also, but to a less extent, by silver and gold.

Mispickel is sometimes dispersed through granites, schists, and serpentines, and sometimes occurs in threads and nests in metalliferous veins, especially in those containing tin, silver, and lead. It has been found in Saxony, Bohemia, Styria, Sweden, United States, and Cornwall. *Danaite* and *glaucodote* are varieties containing cobalt; crystals of the latter found at Orawitza in the Bannat have contained only 4·5 per cent. of iron, and 32 per cent. of cobalt, and ought, therefore, perhaps, to be referred to danaite, as a distinct species, or as a sulpharsenide of cobalt isomorphous with sulpharsenide of iron.

PYRRHOTIN. (*Syn.* Magnetic Iron Pyrites; Magnetic Pyrites.)

No formula is assigned to this, for the reason that while some mineralogists make it an indefinite mixture of two simple sulphides of iron, others make it a definite compound of two other kinds of sulphide of iron. The percentage composition is generally admitted to be, sulphur 39·6; iron 60·4.

Its crystals are usually six-sided tables belonging to the hexagonal system. The primary form is a hexagonal prism, which has a distinct basal cleavage, but an indistinct one parallel to the vertical faces. Crystals, however,

are rare, and it is generally met with in granular amorphous masses. It has a slight metallic lustre; a reddish bronze yellow colour; a dark greyish black streak and powder; a sp. gr. of 4·5 (50,601)—4·6 (51,418); a sp. ht. of ·160; and a hardness of 3·5 to 4·5, which is less than that of the other iron pyrites. It is brittle, breaks with a subconchoidal fracture, readily tarnishes, and is slightly magnetic. When heated in a test tube sulphurous acid is evolved, and when melted by the reduction flame the same thing occurs, leaving a magnetic black globule. It is soluble in dilute acids with separation of sulphur and evolution of sulphuretted hydrogen.

Pyrrhotin has been found in meteoric stones, and in the older crystallised rocks. Amongst other localities may be mentioned Bodenmais, Bavaria, associated with cordierite and orthoclase; Breitenbrunn, Saxony; various places in the Harz, Norway, Sweden, France, United States, Mexico, Brazil, and in Cornwall, associated with ores of tin and copper.

STERNBERGITE. ($Fe_2 Ag S_3$ or Fe = 35·6; Ag = 34·1; S = 30·3. *Syn.* Sulphide of Silver and Iron.)

It occurs in pinchbeck brown hexagonal plates, derived from a right rhombic prism, with an angle of 119° 30′, which yield a black powder, possess a metallic lustre, and readily cleave in a direction parallel to the modifying faces of the four basal edges. Its faces are often tinged with a bluish iridescence. The thin laminæ have considerable flexibility. It has a sp. gr. of 4·2 (46,947), a hardness of 1·5, and marks paper like black lead. Before the blowpipe it gives the reactions of iron and silver. It is found at Joachimsthal, Saxony, associated with various argentiferous minerals, such as argentite, and pyrargyrite.

LINNÆITE. ($Co_3 S_4$ or Co = 57·9; S = 42·1. *Syn.* Siegenite; Cobalt Pyrites.)

This is probably a combination of the proto- and sesqui-sulphides of cobalt. It crystallises in regular octa-

hedrons and cubes which present no apparent cleavage; the colour is silver white, with a reddish or yellowish tinge; the lustre metallic; the fracture uneven; the hardness 5·5; and the sp. gr. 4·9 (54,772). It is distinguished from smaltine and cobaltine by not giving any arsenical odour when heated. Before the blowpipe the sulphur is driven off, and a grey globule of cobalt is left, which forms a blue flux with borax. The cobalt is usually replaced to a greater or less extent by iron, nickel, and copper. The nickeliferous variety is called *Siegenite*, and may be represented by the formula $\overline{Ni : Co_3}\ S_4$; the cupriferous variety is called *Carrolite;* other varieties are formed by the partial substitution of bismuth for sulphur. Linnæite is very rare, and especially so in the crystalline state. At Bastnäs, in Sweden, it forms brilliant granular masses in gneiss, and is associated with copper pyrites and hornblende; at Loos, Helsingland, it is associated with pyrites, arsenical cobalt, sulpharsenide of nickel, and native bismuth; at Müsen, near Siegen, Prussia, it is associated with iron pyrites, copper pyrites, carbonate of iron, and galena. It has also been found in the United States.

Copper Pyrites. (Cu Fe S_2 or Cu = 34·8; Fe = 29·8; S = 35·4. *Syn.* Chalcopyrite; Towanite; Yellow Copper Ore; Sulphide of Copper and Iron.)

This mineral is a combination of sulphide of copper with bisulphide of iron. It forms hemihedral crystals belonging to the dimetric system, and occurs in tetrahedrons and octahedrons, which have considerable resemblance to those of the regular system, but are distinguishable by the angles being different. In the regular octahedron the angle made by the terminal faces is 109° 28′, while in the octahedron of copper pyrites it is 109° 53′. It possesses cleavages in two directions, but neither of them are very distinct. Copper pyrites is also met with in dendritic, concretionary, and compact masses. It has a greenish brass yellow colour, which

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becomes more or less iridescent by tarnishing, while the streak and powder are greenish black. The lustre is metallic; the sp. gr. 4·1—4·3 (48,055); the sp. ht. ·131; the hardness 4; and the fracture conchoidal and uneven. Before the blowpipe the sulphur is evolved in fumes of sulphurous acid, leaving a black globule of copper and iron, which is attracted by the magnet. It dissolves in nitric acid with separation of sulphur; and the solution is turned blue by ammonia with the separation of oxide of iron.

It is from this mineral that the great bulk of the copper of commerce is obtained. It is the most common of the copper ores, but, compared with most, it contains but little copper; for instance, copper pyrites has 34 per cent.; azurite 55 per cent.; malachite 57 per cent.; melaconite 80 per cent; and the red oxide 88 per cent. In each case, however, the yield is generally much less, owing to the presence of impurities, as exemplified in the principal Cornish copper ore, which is a copper pyrites largely mixed with iron pyrites, and yielding from 3 to 12 per cent. of copper.

Copper pyrites occur in the more highly crystalline rocks, such as gneiss, talcose schist, argillaceous schist, as also in sedimentary deposits, especially where they are traversed by mineral springs and serpentinous rocks. There is a fine collection of specimens of this mineral in the Museum of Practical Geology, which comprises specimens from Cornwall, Devonshire, Wales, and Ireland. The most celebrated mines in Europe are at Röraas, Norway; Fahlun, Garpenberg, and Nya Koppar-berg, Sweden; at Rammelsberg in the Harz, where it forms beds in a schistose rock, and is associated with iron pyrites, blende, and galena; at Monte Catini, Tuscany, in the rock called *gabbro*, where it is associated with bornite. There are a few mines in France, as at Chessy, Baigorry, Chalanches, Giromagny, and St. Marie aux Mines, but none of them are extensive. This mineral is also met with abundantly in South Australia and North America; in the latter country it is sometimes associated with gold and quartz veins.

It is distinguished from iron pyrites by its smaller

specific gravity and hardness; and from gold by its brittleness and its solubility in nitric acid. By alteration it becomes converted into malachite, covelline, chrysocolla, black copper, copper glance, and oxide of iron.

Tin Pyrites. (*Syn.* Bell-metal Ore.)

This is a complicated combination of the sulphides of iron, tin, and copper, for which numerous formulæ have been proposed. Perhaps the best is $(CuS + FeS)_2$ $Sn S_2$ as proposed by Kudernatsch and Rose. It crystallises in rectangular prisms, which are believed to be quadratic prisms rather than cubes. It has a greenish grey colour, a black powder, a specific gravity of 4·5 (50,301), a hardness of 4, and an uneven conchoidal fracture. When fused by the blowpipe on charcoal, it forms a white powder of oxide of tin. It is partially soluble in nitric acid, with the formation of a white precipitate which is soluble in hydrochloric acid. The nitric acid solution is rendered blue by ammonia, which also separates the oxide of iron. It is a rare mineral, and is scarcely known out of Cornwall. It is associated with copper pyrites, ordinary pyrites and blende, at the Huel Rock mine, at St. Agnes; and with blende and galena at Zinnwald, in the Erzgebirge.

Geocronite. (5 PbS. Sb_2S_3 or Pb = 67·5; S = 16·6; Sb = 15·9. *Syn.* Sulphantimonite of Lead.)

It usually occurs massive, but sometimes in crystals belonging to the dimetric system. It has a light lead-grey colour and streak; a metallic lustre; a conchoidal fracture; a specific gravity of 6·5 (72,657), and a hardness of from 2 to 3. It is readily fusible by the blowpipe, giving the reactions of lead, sulphur, antimony, and sometimes arsenic. Its localities are the silver mine at Sala, and the copper mine at Fahlun, Sweden; at Meredo, Spain; and at Pietro Santo, Tuscany. There are several varieties; one embraces the arseniferous specimens; another (*Kilbrickenite*) those in which the proportion of the two sulphides is as 6 to 1; and a third (*Meneghinite*), from Bottino, Tuscany, those in which the proportion is as 4 to 1.

STEPHANITE. (6 Ag_2S. Sb_2S_3 or Ag = 70·1; Sb = 13·1; S = 15·80. *Syn.* Black Silver; Brittle Silver Glance.)

It occurs in tables or short prisms with six sides and modified basal edges, derivable from a rhombic prism with an angle of 115° 39′. The faces of the prism are vertically striated, and the crystals are frequently grouped somewhat in the same way as those of marcasite and arragonite. The cleavages are very indistinct. The colour of the crystals is dark iron-grey, and that of the powder black. The specific gravity is 6·2 to 6·3 (70,411), the hardness 2·5, and the fracture conchoidal. Before the blowpipe the sulphur and antimony are volatilized, and a grey globule is left, which, when reduced with soda, yields a button of silver. The solution formed by treating it with hot nitric acid precipitates silver on a copper-plate. It is one of the richest of the silver ores, and is found in argentiferous veins associated with argentite and pyrargyrite. Beautiful specimens have been obtained from various localities in Saxony, Bohemia, Hungary, and Mexico.

TETRAHEDRITE. (*Syn.* Grey Copper Ore; Fahlerz.)

This embraces a group of minerals in which one atom of a sesquisulphide with antimony and arsenic as a base is combined with four atoms of a monosulphide having as a base one or more of the following metals, viz., copper, silver, iron, zinc, and quicksilver. The crystalline form is some hemihedral modification of the cube, the most common being the tetrahedron (Fig. 33); the colour varies from lead-grey to iron-black; the specific gravity from 4·3 (58,055) –5·2 (58,125); the hardness from 3 to 4. There are numerous varieties differing slightly in their characters according as one or other of the ingredients predominates. Thus *tennantite* is an arseniferous variety of a dark lead-grey colour, and with a reddish-grey powder; the rhom-

Fig. 33.

bododecahedron is the prevailing crystalline form, and the cleavage parallel to its faces the most distinct. Before the blowpipe it burns with a blue flame, gives off the odour of arsenic, and yields a scoria which is slightly magnetic. It exists in several of the copper mines of Cornwall; and at Skutterud and Modum, in Norway; as also in Tuscany and Algeria.

Binnite also is an arseniferous tetrahedrite, occurring in the Binnenthal in brilliant black crystals having a trapezohedral form, and yielding a reddish powder. Its specific gravity is 4·4.

The grey copper ores form beds and threads in schists and other of the more ancient slightly metamorphosed sedimentary deposits, and are found in almost all countries where metalliferous lodes abound. They are mined for in Saxony, Hungary, Transylvania, the Harz, Thuringia, Baden, France, Algeria, England, Sweden, Mexico, Peru, and Chili.

Wölchite.

This appears to be an arseniferous sulphantimonite of lead and copper. It crystallises in right rhombic prisms, modified on the vertical edges and basal faces, but whose precise form has not been satisfactorily determined. It is brittle, and has a blackish lead-grey colour, both in the mass and in powder; the fracture is imperfectly conchoidal; the cleavage distinct parallel to the short diagonal; the specific gravity 5·7 (63,714)—5·8 (64,832); the hardness 3; and the lustre metallic. Before the blowpipe on charcoal it melts with ebullition, giving rise first to a deposit of white oxide of antimony, then of yellow oxide of lead, and finally yielding a lead-grey metallic button, from which copper may be reduced by the aid of soda. It colours the oxidizing flame green, and the deoxidizing flame red. Wölchite is found in the carbonate of iron deposits, at Wölch or St. Gertraud, in the valley of Lavant, Carinthia.

Chiviatite. (2 (Pb : Cu) S. 3 Bi_2 S_3.)

A sulphide of lead and bismuth found in crystalline

foliated masses at Chiviato, Peru. It has three cleavages in one zone, of which one makes an angle of 153° with the second, and of 133° with the third. The colour is lead-grey; the lustre metallic; and the specific gravity 6·92 (87,351). In its behaviour before the blowpipe and with the stronger mineral acids it resembles aikinite.

AIKINITE. (Bi Pb Cu S_3 or Bi = 35·9; Pb = 36·4; Cu = 11; S = 16·7. *Syn.* Patrinite; Aciculite; Belonite; Needle Ore; Acicular Bismuth.)

It has some analogy to Bournonite in composition, containing bismuth in the place of antimony. It crystallises in rhombic prisms with an angle of 110°, which usually form long needles, frequently deformed by curves and transverse fissures. The prisms cleave readily in the longitudinal direction. The colour is lead-grey tinged occasionally with yellow; the specific gravity is 6·75 (75,451), and the hardness is 3. When acted on by the blowpipe flame, it melts with disengagement of the sulphur and the formation of a white and yellow deposit which yields copper when melted with soda. When placed in nitric acid it is partially dissolved, while the sulphur and sulphate of lead are precipitated. It has been found in the auriferous quartz veins in Siberia, where it is associated with azurite and malachite, which it is thought may be the products of the decomposition of the aikinite itself.

BOURNONITE. (Sb Pb Cu S_3 or Sb = 25·14; Pb = 42·3; Cu = 12·99; S = 19·67.)

It crystallises in right rectangular prisms, having the secondary faces more fully developed than those of the primary, so that they frequently present the appearance of rectangular tables, modified on their edges and angles. The colour in mass and in powder is steel-grey, approaching black; the lustre is metallic; the specific gravity 5·7 (63,714)—5·8 (64,832); and the hardness 2·5. It readily melts before the blowpipe, giving rise to white fumes of antimonious oxide, a yellow deposit of oxide of lead, and to a richly cupriferous slag. It partially dissolves in

nitric acid, a portion being deposited as a precipitate; the solution is turned blue by the addition of ammonia, and covers a plate of zinc with lead when immersed in it.

It is generally found in the plumbiferous and cupriferous deposits of the older schists, where it is associated with galena, antimonite, blende, copper pyrites, &c. The principal gangues are quartz, calcspar, and barytine. It is not an abundant mineral, but occurs in Cornwall, the Harz, Saxony, Transylvania, Hungary, Switzerland, France, Chili, Peru, and Mexico. In the last-mentioned country it is associated with tetrahedrite, malachite, and calcspar.

BOULANGERITE. (3 PbS. $Sb_2 S_3$ or Pb = 58·9; Sb = 23; S = 18·1. *Syn.* Embrithite; Sulphantimonite of Lead.)

It is not known to what crystalline system it belongs. It occurs in amorphous masses, having a crystallo-laminar or fine-grained structure, and in bacillar aggregations, the colour of which is a dark lead-grey, while the powder is still darker. It has a specific gravity of 5·8 (64,832), and a hardness of 3. When melted before the blowpipe, it yields a deposit of the oxide of antimony and lead, mingled with a brittle metallic lead. It dissolves in hydrochloric acid, with evolution of sulphuretted hydrogen. It is liable to considerable alteration by which its characters are modified. It is accompanied by quartz, pyrites, and antimonite, at Molières, France; and with antimonite, pyrites, and mispickel at Nertchinsk, Siberia; it has also been found at Bottino in Tuscany; and at Nasafjeld in Lapland, and a few other localities.

KOBELLITE.

This appears to be a compound containing the sulphides of lead, antimony, and bismuth, the crystalline form of which has not been ascertained. It occurs in fibrous radiated masses in the cobalt mine of Hvena, Sweden. It has some resemblance to antimonite, but has a brighter lustre. The colour is lead-grey, that of the powder being black, and the sp. gr. 6.3 (70,311). When melted with the blowpipe on charcoal it yields a yellow and white de-

posit, and a white metallic globule. It dissolves in strong hydrochloric acid with evolution of sulphuretted hydrogen.

PYRARGYRITE. ($Ag_3 Sb S_3$, or $3 Ag_2 S. Sb_2 S_3$ or Ag = 59·77; Sb = 23·52; S = 17·71. *Syn.* Red Silver; Ruby Silver; Aerosite; Black Silver; Sulphantimonite of Silver.)

Its crystals belong to the hexagonal system, and are derivable from an obtuse rhombohedron, in which the angle made by the terminal edges is 108° 20′. They are usually regular six-sided prisms and scalenohedrons, sometimes hemihedrally modified; and they cleave parallel to the faces of the primary rhombohedron. The colour is a bluish or blackish lead-grey, tinged in places by the carmine-red which is exhibited by the streak or fractured surface; the fracture is conchoidal; the lustre adamantine or metallic; the hardness 2 to 2·5; and the sp. gr. 5·7 (63,714) to 5·9 (65,950). When melted on charcoal, which it readily does before the blowpipe, it gives off fumes of antimony and sulphurous acid, and leaves a globule of silver; when treated with hot nitric acid, the silver is dissolved, and sulphur and antimonious oxide deposited; and when treated with hydrochloric acid, the deposit formed consists of chloride of silver.

It is generally crystallised, but sometimes occurs in botryoidal and concretionary masses. Its usual situations are in lodes containing argentite and argentiferous galena, and the principal localities are in the Harz, Saxony, Bohemia, Hungary, Spain, France, Norway, Cornwall, and Mexico. It is sometimes altered into argentite, probably from antimonite being the more soluble of the two minerals.

PROUSTITE. ($3 Ag_2 S. As_2 S_3$, or Ag = 65·38; S = 19·46; As = 15·16. *Syn.* Light Red Silver Ore; Sulpharsenite of Silver.)

It resembles pyrargyrite in colour and form, but may be distinguished by its lighter tint. Its crystals are derived from an obtuse rhombohedron, in which the angle of the terminal edges is 107° 49′, and in all the modified

forms there are correspondingly slight differences in the angles. The streak, hardness, fracture, cleavages, are the same as in pyrargyrite; but the lustre is rather less metallic, and the sp. gr. is only 5·4 (60,361) to 5·5 (61,479). The blowpipe reactions are similar, proustite being distinguished by the garlic-like odour afforded by the arsenic. It is met with in the same localities as pyrargyrite, but far less abundantly.

WITTICHITE. ($3\,CuS.\,Bi_2S_3$.)

This resembles aikinite. Chemically it differs from it in the substitution of copper for lead. It occurs in light steel-grey needles, readily cleavable in the longitudinal direction, at Wittichen, in the Black Forest.

POLYBASITE. ($9\,Ag_2S.\,Sb_2S_3$ or Ag = 75·2; S = 14·9; Sb = 9·9.)

It crystallises in hexagonal prismatic tables, the terminal faces of which are marked with striæ which cut each other at an angle of 60°, and consequently form triangles. There are also longitudinal striæ on the faces of the hexagonal prism. The terminal edges make an angle of 129° 30′. There is an imperfect basal cleavage. Both crystals and powder are of a deep iron-black, but their laminæ appear reddish by transmitted light. The lustre is metallic; the hardness 2·3; the sp. gr. 6·21 (69,415), and the fracture uneven. The antimony is generally partially replaced by arsenic, and the silver by copper, which in some specimens forms as much as 10 per cent. of the mineral. Stephanite and iron pyrites are occasionally met pseudomorphous after polybasite. The principal localities are at the Guanaxuato and Guarisamey mines, Durango province, Mexico, associated with copper pyrites and calcareous spar; at the mines near Freiberg, Saxony; and in those of Joachimsthal, Bohemia, and of Schemnitz, Hungary.

FREIESLEBENITE. ($\overbrace{Sb_3 : Ag_3}\,S_6.\,2\,PbS$. *Syn.* Antimonial Sulphide of Silver.)

It occurs in monoclinic crystals, derivable from a right

rhombic prism, with an angle of 99° 48′, and having a distinct cleavage parallel to the faces of the prism; there are also cleavages in two other directions, but they are less distinct. The crystals are striated in a longitudinal direction; have a light lead-grey colour, a metallic lustre, a conchoidal fracture, a hardness of 2·25, and a sp. gr. of 6·2 (69,303) to 6·4 (71,539). They are opaque, brittle, and readily scratched with a knife. Before the blowpipe on charcoal it gives off white vapours and a sulphurous odour, deposits the oxides of antimony and lead on the charcoal, and yields a globule of silver, which sometimes contains copper. It is a very rare mineral, and has been found at the Himmelsfürst mine, near Freiberg, in gneiss associated with carbonate of iron, argentite, galena, and blende in a quartzose gangue; as also at Kapnik, Transylvania; Ratiborschitz, Bohemia; and Hiendelencina, Spain. The above formula seems to show that Freieslebenite is an isomorphous mixture of 3 parts by weight of argentite = $3\,Ag_2S$; 3 parts of antimonite = $3\,Sb_2S_3$; and 4 of galena = 4 PbS. The association of galena and argentite is probably due to water having carried off the more soluble antimonite.

Brongniardite. (2 Pb AgS. Sb_2S_3.)

This is a sulphantimonite of lead and silver, usually occurring in amorphous masses, showing no signs of cleavage or crystallisation. A few specimens have been found in Bolivia with crystals intermediate between the regular octahedron and rhombo-dodecahedron. It has a metallic lustre, a greyish black powder, and a sp. gr. of 5·95 (66,509). It readily melts before the blowpipe, giving off white vapours with a sulphurous odour, and yielding a globule of silver amidst a deposit of yellow oxide of lead. It is also found in Mexico.

Jamesonite.

A sulphantimonite of lead, whose crystals belong to the trimetric system, the dominating form of which is a rhombic prism with angles of 101° 20′, and 78° 40′. It is also

found in bacillar and fibrous masses, with delicate fibres arranged in a divergent manner. The cleavage parallel to the base is the most distinct; while others, parallel to the faces and short diagonal of the prism, are less distinct. It has a dark steel-grey colour, a metallic lustre, a hardness of 2·5, and a sp. gr. of 5·5 to 5·8 (64,832). It is readily fused by the blowpipe, but decrepitates; in other respects its behaviour is like that of zinkenite. Its principal locality is Cornwall, where it is associated with quartz and bournonite; there are other localities in Spain, Hungary, Tuscany, Siberia, and Brazil.

HETEROMORPHITE. (2 PbS. Sb_2S_3 or Pb = 49·71; Sb = 30·97; S = 19·32. *Syn.* Plumosite; Feather ore.)

A sulphantimonite of lead, which crystallises in exceedingly flexible fibres, interlaced in all directions, so as to present the appearance of a cobweb; it also forms compact masses having an imperfectly compact structure. It probably belongs to the trimetric system; but this is uncertain, as the dimensions of the prisms are not known. Its colour is between lead-grey and steel-grey, sometimes modified by iridescence; the lustre submetallic or silky; the hardness 3; and the sp. gr. 5·7 to 5·9 (66,950). It behaves like zinkenite before the blowpipe. It is met with in metalliferous veins associated with antimonite (with which it is often confounded), zinkenite, galena, and plagionite. Wolfsberg, in the Harz, is the principal locality; and less important are Andreasberg, Clausthal, Freiberg, Schemnitz, Pfaffenberg, Meiseberg, and Bottino.

DUFRENOYSITE. (2 PbS. As_2S_3 or Pb = 57·2; S = 22·1; As = 20·7).

This is a sulpharsenite of lead, but the name is frequently given to what we have called *binnite*, which is a sulpharsenide of copper. Dufrenoysite resembles heteromorphite in its chemical composition, and differs from it only in containing arsenic instead of antimony. Its crystals are right rhombic prisms, derivable from a fundamental prism with an angle of 118°. There is a slight

basal cleavage, but a more distinct one parallel to the shorter diagonal. The colour is between lead-grey and steel-grey in the crystals, and reddish brown in the powder. It is very brittle, crumbling down between the fingers, and has a sp. gr. of 5·4 to 5·5 (61,479). When heated in the blowpipe flame on charcoal it readily melts, giving rise to the odours of heated sulphur and arsenic, and leaving a globule of lead in the midst of a yellow deposit. It is found in the Binnenthal, associated with the crystals of realgar, and less frequently with orpiment, blende, and yellow pyrites.

PLAGIONITE. (5 PbS. 4 Sb_2S_3 or Pb = 40·74; Sb = 37·86; S = 21·40.)

A sulphantimonite of lead occurring in monoclinic prisms, derivable from an octahedron in which the axes a : b : c are as 1 : 0·88 : 0·37. The colour is a blackish lead-grey; the basal faces are smooth, and more brilliant than the others, which are striated; the lustre is metallic; the hardness 2·5; the sp. gr. 5·4 (60,631). It is readily melted by the blowpipe, but with decrepitation; fumes of sulphur and antimonious oxide are given off, and a few globules remain covered by a yellowish deposit of oxide of lead. It is found at Wolfsberg, in the Harz, along with antimonite, zinkenite, bournonite, and heteromorphite.

GRUNAUITE. (*Syn.* Saynite; Nickel-bismuth Glance.)

This is a native sulphide of bismuth and nickel, regarded by some mineralogists as a distinct species, and by others as a variety of Linnæite. It is found at Grunau, in the district of Sayn-Altenkirchen, Westphalia, associated with quartz and copper pyrites. Its lustre is metallic; its colour steel-grey, with a slight dash of yellow; its hardness is 4·5; and its sp. gr. 5·14 (57,454). It crystallises in octahedrons and cubes, and has an octahedral cleavage.

WOLFSBERGITE. (CuS. Sb_2S_3 or Sb = 50·26; S = 25·08; Cu = 24·66.)

A sulphantimonite of copper, frequently occurring in tables derivable from a right rhombic prism of 135° 12′, and having a blackish lead-grey colour, sometimes variegated with iridescent tints. The powder is black and dull; the fracture imperfectly conchoidal and uneven; the hardness 3·5; and the sp. gr. 4·7 (52,536). It decrepitates before the blowpipe; melts easily; covers the charcoal with a white deposit; and yields a metallic button, from which copper may be reduced by means of soda. It is found at Wolfsberg, in the Harz, mixed with quartz, frequently covered with copper pyrites, and associated with heteromorphite, antimonite, and zinkenite; also at Guadez, in Spain.

BERTHIERITE. (3 FeS. 2 Sb_2S_3. *Syn.* Haidingerite).

It has only been met with in crystalline or confusedly bacillar masses, presenting cleavages in several directions. The colour is iron-black or dark steel-grey; the lustre is metallic; the hardness 2·3; and the sp. gr. 4·28 (47,841). Fuses readily before the blowpipe on charcoal, giving off a sulphurous odour and antimonial fumes, and leaving a black globule, which is attracted by the magnet. It dissolves in nitric acid, with precipitation of white antimonious oxide; while a blue precipitate is thrown down from the solution by ferrocyanide of potassium. It is found in the Martouret mine, near Chazelles, Auvergne, and near Padstow, in Cornwall.

ZINKENITE. (PbS. Sb_2S_3 or Sb = 43·45; Pb = 34·87; S = 21·68.)

The primary crystalline form is a dimetric octahedron with angles of 163° 32′, 150° 56′, and 33° 36′; these occur grouped together in threes, so as to form what has been taken for a regular six-sided prism with longitudinally striated faces. The colour and streak are steel-grey, sometimes with a bluish or iridescent tinge; the

fracture is uneven; the lustre metallic; the hardness 3·5; and the sp. gr. 5·3 (59,233). It decrepitates when heated by the blowpipe flame, melts with facility, and yields white fumes of antimony, a yellow deposit of oxide of lead, and a globule of lead when fused with soda. Nitric acid dissolves it with precipitation of a white powder containing antimony. It has been found at Wolfsberg, in the Harz, associated with hyaline quartz, antimonite, and heteromorphite; and near St. Trudpert, in the Black Forest.

MIARGYRITE. ($Ag_2S.\ Sb_2\ S_3$ or Ag = 36·75; Sb = 41·49; S = 21·76.)

This resembles pyrargyrite in many of its properties, and, like it, is a sulphantimonite of silver, but it contains less silver and more antimony. It occurs in monoclinic prisms with striated lateral faces, and an imperfect cleavage parallel to those faces. The colour is steel-grey or iron-black in the mass; but their laminæ are blood-red by transmitted light, and the powder is a dark cherry-red; the fracture is subconchoidal; the lustre adamantine or submetallic; the hardness 2 to 2·5; and the sp. gr. 5·2 to 5·4 (60,631). Its blowpipe reactions are like those of pyrargyrite. It has as yet been found only at Bräunsdorf, Saxony; but it is possible that some of the localities assigned to pyrargyrite belong to miargyrite. The antimony is sometimes partially replaced by arsenic, as in the variety called *hypargyrite*, from the mines at Clausthal.

ENARGITE. ($3\ CuS.\ As_2\ S_5$ or Cu = 48·6; S = 32·53; As = 18·82.)

A sulpharsenate of copper, crystallising in trimetric prisms with an angle of 97° 53′, and a perfect cleavage parallel to the faces of the rhombic prism. It is very brittle, and has an iron-black colour, a metallic lustre, an uneven fracture, a hardness of 3, and a sp. gr. of 4·3 to 4·4 (49,183). It decrepitates when heated, easily melts before the blowpipe, and yields vapours of arsenic and a

white deposit on the charcoal. It is soluble in nitro-muriatic acid. Its localities are Morococha, Peru; New Granada, Chili; Cosihuarichi, in Mexico; Chesterfield, S. Carolina; Colorado; and in Alpine co., California.

Barnhardtite.

A sulphide of copper and iron, found at various localities in N. Carolina. It has a bronze yellow colour, a conchoidal fracture, a metallic lustre, sp. gr. of 4·5, and a hardness of 3·5. It readily tarnishes in the air, and acquires a rose-red colour.

Arsenargentite.

The existence of an arsenide analogous to domeykite is indicated by a mineral found in the museum of the Glasgow University. It consists of acicular trimetric crystals in metallic arsenic. Their composition was 81·37 per cent. of silver and 18·43 of arsenic, which answers to Ag_3 As. The sp. gr. is 8·825.

Coloradoite. (Hg Te.)

A telluride of mercury found in the massive state. The hardness is 3, the sp. gr. 8·627, the lustre metallic, the colour iron black, inclining to grey, and the fracture uneven to subconchoidal. It slightly decrepitates when heated in the tube, fuses, and yields metallic mercury as a sublimate, tellurium trioxide in drops, and metallic tellurium near to the assay. Nitric acid dissolves it. It occurs in small quantities at the Keystone, Mountain Lion, and Smuggler Mines in Colorado.

Schreibersite.

Some flexible magnetic flakes have been found in meteoric iron which seems to be essentially a phosphide of iron and nickel, having a hardness of 6·5 and a sp. gr. of 7·01.

Oldhamite.

This is another mineral found in aerolites. It is a sulphide of copper containing a small amount of sulphide of magnesium. The spherules show indications of a cubic cleavage. The hardness is 4, and the sp. gr. 2·58. Colour pale chestnut brown, transparent when pure. It readily dissolves in acids with the evolution of sulphuretted hydrogen and deposition of sulphur. It occurs in granules which are generally coated with a thin film of sulphate of lime, and embedded in enstatite or augite in the Busti and Bishopville meteorites.

Troilite.

A mineral found in meteorites, which closely resembles pyrrhotin in appearance and in many of its properties. It contains nearly the same proportionate amount of sulphuric and of iron, but differs in being a true protosulphide of iron. The hardness is 4; sp. gr. 4·8. It occurs in the meteorite which fell at Albareto, in Modena, and in several which have fallen in Tennessee. But almost all meteoric irons contain this particular sulphide of iron in small nodules, which are scattered more or less plentifully through the general mass of the iron.

Erubescite. (CuFeS. *Syn.* Purple Copper Ore.)

It occurs in crystals belonging to the regular system which show traces of octahedral cleavage. In the closed tube it gives a faint sublimate of sulphur when heated, while in the open tube it yields sulphurous acid, but no sublimate. Nitric acid dissolves it with separation of sulphur. It is a very abundant and valuable ore of copper, occurring at Ross Island, Killarney, Ireland; at Mount Catini, Tuscany; in shale around Mansfeld in Germany; in Norway, Siberia, Silesia, Hungary, Chili, Peru, Bolivia, Mexico; at Bristol,

Connecticut, and at numerous places in the United States and Canada. Fine crystals have been found in Cornwall, especially near Redruth.

Guadalcazarite.

Although it approaches cinnabar in chemical composition it differs from it markedly by its physical properties. The specimens found hitherto have been more or less altered, the sulphur having partly given place to selenium and the mercury to zinc. It has generally been found in masses, but a few rhombohedral crystals have been observed. The hardness is 2—3; the colour deep black; streak bluish black, and the sp. gr. only 7·15; lustre metallic. When heated on charcoal before the blowpipe it first decrepitates, giving off mercurial fumes, and an odour due to the selenium; afterwards it deposits oxide of zinc and gives a distinct reaction for cadmium. In the open tube it deposits a sublimate grey to black in colour, composed of mercury, sulphur, and selenium; gives off sulphurous acid, and a yellowish oxide of zinc remains behind. Aqua regia dissolves it with the separation of some of the sulphur. It occurs at Guadalcazar, in Mexico, associated with cinnabar, quartz, and baryta; and in the Redington Mine, California.

Syepoorite. (CoS or Co. = 64·8; S = 35·2.)

A pure but massive sulphide of cobalt, having a sp. gr. of 5·45, and a steel-grey colour inclining towards yellow. It is found in some schists along with pyrrhotin at Syepoor, near Rajpootana.

Guanajuatite. ($Bi_2 Se_3$.)

Its chemical constitution is analogous to that of bismuthine, like which it occurs in acicular crystals of

the trimetric system; strongly striated vertically; hardness 3; sp. gr. 6·25; colour bluish grey, streak greyish black and shining, and lustre metallic. It is readily fused by the blowpipe on charcoal, yielding a blue flame, and giving out a strong odour indicative of selenium. With iodide of potassium a fine red coating is obtained, showing the partial replacement of selenium by sulphur. When slowly heated in aqua regia it is decomposed. It is found near Guanajuato, in Mexico.

Crookesite.

This name has been given to a selenide of copper and thallium found along with berzelianite at Skrikerum, in Norway; for which mineral it was formerly mistaken. It contains 17 per cent. of thallium. It readily fuses, colouring the flame green, is soluble in nitric, but insoluble in muriatic acid.

Wolfachite.

The formula assigned to this mineral is $Ni\,S_2 + Ni\,(As\,Sb_2)$. It occurs in trimetric crystals coating niccolite. H. 5·5; sp. gr. 6·372; lustre metallic, colour silver white to tin white, streak black. It is soluble in nitric acid. It is found at Wolfach, in Baden.

Corynite.

Its chemical composition is the same as that of Wolfachite, but it crystallises in octahedrons with convex faces, and therefore belongs to a different system, viz. the isometric. Hardness 4·5—5; sp. gr. 5·95—6·02. It is found at Olsa in Carinthia.

Daubreelite. ($Fe\,S + Cr_2\,S_3$.)

A sulphide of chromium and iron which is usually found massive, but occasionally in scales having a crystalline structure and a cleavage in one direction. Sp. gr. 5·01; lustre metallic, brilliant. Colour black.

It is infusible before the blowpipe, but it loses lustre, and in the reducing flame becomes magnetic. With borax gives the reaction for chromium. Hydrochloric acid has nó effect upon it, but nitric acid dissolves it without liberating any sulphur. It occurs in close association with troilite in the meteoric iron of Coahuila, Mexico; and has also been met with in the mines of Toluca, Mexico ; Sevier, Tennessee; and of Cranbourne, Australia.

Rionite.

A sulpharsenide of copper and bismuth having a conchoidal fracture, an iron-black colour, a black streak and a greasy metallic lustre. It is found associated with chalcopyrite at Cremenz, in Switzerland, where it is worked as a bismuth ore.

Diaphorite.

It has the same chemical composition as Freieslebenite, but is distinguished therefrom by its crystals, which belong to the trimetric system, by its greater hardness, which is 2·5 to 3, and its lower sp. gr. which is 5·9. The localities for it are Przibram, Braunsdorf, and Freiberg.

Tiemannite.

A selenide of mercury found in compact masses. Hardness 2·5; sp. gr. 7·1—7·3; lustre metallic, and colour steel-grey. On charcoal it volatilizes, colouring the outer flame azure blue, and giving a lustrous metallic coating. It occurs with chalcopyrite near Zorge, in the Harz; at Tilkerode; near Clausthal; and near Clearlake in California.

Chalcomenite.

This name has been given to the only selenite as yet known native. It is a selenite of copper and mercury. It occurs in monoclinic crystals which are usually prisms. Sp. gr 3·76. Colour bright blue, transparent.

Before the blowpipe on charcoal it fuses to a black slag, giving off fumes of selenious acid and colouring the flame deep blue. With salt of phosphorus in the oxidizing flame it yields a greenish blue glass, which becomes blood red when reduced with the addition of metallic tin. Soluble in acids. It has been obtained in the selenides of silver, copper, and lead, found in the Cerro de Cacheuta, Mendoza, Argentine Republic. M. Friedel and Sarrasin have formed it artificially.

CHAPTER V.

Chlorides, Bromides, Fluorides, and Iodides.

Rock Salt. (Na Cl or Na = 39·3; Cl = 60·7. *Syn.* Common Salt; Chloride of Sodium.)

It belongs to the regular system, and rarely occurs in any other form than the cube. It possesses perfect cubic cleavage. It is generally transparent and colourless, but is sometimes tinged red, yellow, grey, blue, and greenish, which colours can in most cases be driven off by heat. The specific gravity is 2·2 (24,591); the hardness 2. Its index of refraction is 1·545, and sp. ht. ·213. It is highly transparent to the rays of heat, and is the only substance known that transmits all kinds with equal facility. It is readily soluble in water, but not more so in hot than in cold. The salt formed by artificial evaporation of saline water decrepitates when thrown on the fire, in consequence of the gas entangled with it. The same property is found in the rock salt of Wieliczka, which differs in this respect from most other native specimens.

When a solution is treated with sulphuric acid, sulphate of soda is formed. Rock salt may be fused by means of the blowpipe, and volatilises at a high temperature.

Salt is widely distributed in nature, and occurs either

as a pulverulent substance, in large compact masses or rock salt, or in an aqueous solution. Thick beds are formed of it, extending over large areas of country, some of which are 80 or 100 feet thick. They are most abundant in strata of Triassic age, and are nearly always associated with marls and gypsum. The mine at Wieliczka, near Cracow, is remarkable both for its magnitude and its antiquity. It has been worked since the year 1251, and still contains sufficient salt to supply the wants of many centuries more. The excavations already executed form galleries several miles in length; while here and there are several large chambers, some of which are used as chapels. There are three beds; the first is situated about 200 feet below the surface, and the third about 800 feet below the first. Other extensive beds are found in almost every country. Most of the richest brine springs derive their salt from the same Triassic strata, and amongst these may be mentioned those at Droitwich, Cheshire; at Vic and Dieuze, in France; at Schönberg, near Magdeburg; and at various places in the United States. The pulverulent variety impregnates the soil of many of the large deserts of Asia and Africa; and the ocean and numerous lakes are saline solutions of different strength, the strongest being the Dead Sea, Lake Oroomiah, in Persia, the Great Salt Lake of North America, and the salt lakes of the Kirghis steppes. It is difficult to explain the formation of large beds of salt, but there are many circumstances to indicate that in the majority of instances they have been gradually formed by deposition from water, and not by ejection from the interior of the earth, as has been maintained by some geologists; amongst others we may notice the occurrence of fossil wood and of small brown beetles in the salt, and of numerous foraminifera in the saliferous clay connected with it. Salt is very soluble, and many substances are pseudomorphous after it; such as gypsum, polyhalite, anhydrite, mica, and sandstone. The last is thus explained by Haidinger:—On the muddy shores of a sea cubes of salt are deposited in consequence of the evaporation of the water; they are covered with dry sand

blown towards the sea; on the return of the water, the salt is dissolved, the vacant spaces filled up with sand, and the whole cemented together. *Martinsite* is a variety of salt containing 10 per cent. of sulphate of magnesia.

SYLVINE. (KCl or K = 52·5; Cl = 47·5. *Syn.* Digestive Salt; Chloride of Potassium.)

It crystallises in cubes, like common salt, with which it is generally associated. It is met with pure in the fumaroles of Vesuvius, in the salt beds of Stassfurth, near Magdeburg, and in the mines at Hallein and Berchtesgaden, in Germany; and it is associated with other chlorides in *carnallite* as well as in sea-water and brine springs. It has the same taste as common salt; a specific gravity of 1·8 to 1·9 (21,238); a sp. ht. of ·171; decrepitates when heated; and volatilises at a somewhat lower temperature than salt without being decomposed. It is soluble in three times its weight of water at about 60° Fahr. It unites with most of the other metallic chlorides, forming double salts.

SAL-AMMONIAC. (ClN H_4 or Cl = 66·3; NH_4 = 33·7. *Syn.* Chloride of Ammonium; Hydrochlorate of Ammonia.)

It crystallises in the regular system, the dominant form being the octahedron, but the trapezohedron and scalenohedron also occur, though rarely. It has no smell in itself, but when treated with caustic soda or potash it has a strong ammoniacal odour; and when heated it volatilises without being decomposed. It has a sharp pungent taste, a specific gravity of 1·5 (16,767), a sp. ht. of ·373, and is soluble in about its own weight of water at 212° Fahr., but is much less soluble in cold water. It is decomposed by most metals, and by many salts, the result usually being the formation of a metallic chloride and the evolution of ammonia; it is also decomposed by exposure to the atmosphere. It is readily formed by heating nitrogenised animal matter along with common salt. It is produced in great abundance in many volcanic districts; sometimes

in such quantities that the people collect it by hundredweights immediately after an eruption, as, for instance, in the eruption of Vesuvius in 1795 and 1855, and that of Hecla in 1845. It is also present in the vapour of the solfatara at Pozzuoli; mixed with sulphur at the island of Vulcano; in the lava streams at Lancerote, and elsewhere. Notwithstanding all this, it is a rare natural product, owing to the readiness with which it is decomposed. In many, and probably most, instances its natural formation has resulted from the action of heat on animal matter in the presence of salt water.

KERARGYRITE. (AgCl or Ag = 75·25; Cl = 24·75. *Syn.* Horn Silver; Corneous Silver Ore.)

It crystallises in the regular system, the prevailing form being the cube. While in its native matrix it is transparent, or translucent, and of a pearly or greenish-grey colour; but when exposed to the light it becomes dark brown or violet-black. The specific gravity is 5·6 (62,596); the hardness 1; and the lustre greasy or adamantine. It is insoluble in water and acids, and deposits silver upon a stick of iron or zinc when rubbed against it. It is easily fusible, and when melted in the inner blowpipe-flame it yields a globule of silver, at the same time giving off a pungent odour. It is not often found in the crystalline state, but generally forms crusts on other bodies, or it is disseminated through various earthy and ferruginous minerals. It is rare in European mines, but common in those of Chili, Peru, and Mexico.

The chlorine is frequently replaced to a greater or less extent by iodine and bromine. The chlorobromides may be regarded as isomorphous mixtures of bromargyrite and kerargyrite, but some mineralogists have considered them to be distinct minerals. Such, for example, are the minerals termed *embolite*, *megabromite*, and *microbromite*. Their specific gravity increases in proportion as there is more bromine, and the colour varies from pearly-green in the specimens containing 8 per cent. of bromine, to dark green in those containing 34 per cent. of the same substance.

BROMARGYRITE. (AgBr or Ag = 57·45; Br = 42·55. *Syn.* Bromite; Bromyrite; Bromide of Silver.)

It usually occurs in small concretions, and rarely in crystals; and then in cubes, octahedrons, and combinations of the cube and octahedron. It is of a yellowish olive-green. It is readily melted by the blowpipe, is sparingly affected by acids, but is soluble in a hot concentrated aqueous solution of ammonia. It is found in Mexico and Chili, where it is associated with the chlorobromides of silver, which, like it, are worked as silver ores.

IODARGYRITE. (AgI or Ag = 45·97; I = 54·03. *Syn.* Iodite; Iodide of Silver.)

It crystallises in the hexagonal system, and occurs either in small hexagonal prisms (some of which resemble those of greenockite), or still more frequently in thin laminæ, having a cleavage parallel to the principal faces. These laminæ are of a citron-yellow colour, have a specific gravity of 5·9 (65,950), a greasy lustre, and possess a slight degree of ductility. Iodargyrite readily fuses, colours the flame red, and yields a globule of silver when reduced. If rubbed when moist against a clean surface of zinc, the iodine unites with the zinc, and leaves the silver in a metallic state. It is found in Mexico, in the Chanarcillo mines, Chili, and at Guadalajara, Spain.

FLUORSPAR. (F_2Ca or F = 48·72; Ca = 51·28. *Syn.* Fluate of Lime; Fluoride of Calcium; Fluorite; Fluor; Ratoffkite; Chlorophane; Blue John; Liparite.)

It crystallises in the regular system, the prevailing forms being the cube with octahedral cleavage, and combinations of the cube and octahedron, such as are represented in Figs. 2, 4, and 12 of Pl. I.; it is also found in forms like Figs. 8, 10, and 17. The simple octahedron is seldom met with, but specimens of a green colour have occurred in Derbyshire, Switzerland, and France. Fluorspar may also be columnar, granular, or laminar. It is highly transparent, and sometimes colourless; but is usually of

various tints of green, yellow, blue, or violet. Its colours are generally bright; the most common are violet with a tinge of green, as in specimens from Durham and Yorkshire, yellow, purple, and red. The rose-red and violet tints are highly prized, as in the specimens from Derbyshire, the Glendalough lead mines, and elsewhere. These colours are readily driven off or modified by the action of heat and electricity: this at once shows that it is not due to any mineral colouring matter. Some persons have attributed it to the presence of organic matter, and others to some ill-understood molecular condition. When heated to a little below redness, it becomes strongly phosphorescent, but if heated above redness it loses both its phosphorescent powers and its colour, a coincidence which seems to point to some relation between the two phenomena. The colour of the phosphorescent light is different from, and is said to be independent of, the external colour, although it resembles it in being of various shades of purple, blue, yellow, and green. This phenomenon is now considered to be quite distinct from ordinary phosphorescence, and Professor Stokes has termed it *fluorescence*.

Chlorophane is a variety which derives its name from its green phosphorescence. The specific gravity of fluorspar is 3·18 (35,446); the hardness 4; the lustre is vitreous; and the index of refraction 1·434. It decrepitates before the blowpipe, and readily melts into an enamel. When treated with hot or strong sulphuric acid it is decomposed, with the formation of hydrofluoric acid, which easily corrodes glass. It is usually more or less impure, containing chlorine or phosphoric acid in the place of a portion of the fluorine; sometimes it is largely mixed with clay, as in the blue earthy variety (*Ratoffkite*), or with silica, as in some of the Cornish specimens. A dark blue variety found at Wulsendorf is said to contain ozone. Waters containing alkaline carbonates decompose it, giving rise to calcspar with the form of fluorspar; there are other pseudomorphs after fluorspar formed by water, such as quartz, limonite, hæmatite, iron pyrites, chlorite, lithomarge, calamine, smithsonite, cerusite.

It is the most abundant of the native compounds of fluorine, being frequent in drusy cavities in dykes traversing gneiss, granite, mica slate, porphyry, diorite, and granular limestone. It sometimes forms the greater portion of the gangue in metalliferous lodes, especially those of lead and tin, and in this form it is commonly associated with galena, blende, calcspar, and hyaline quartz. It occurs in several hot-springs, and in modern volcanic lavas, such as those of Vesuvius, associated with idocrase, augite, hornblende, mica, nepheline, and sodalite.

The massive fibrous fluorspar of Derbyshire takes a high polish, and is worked into vases, candlesticks, and various ornaments. The mineral is turned in a lathe, but its brittleness renders it rather a difficult material to work with. The natural colours are heightened by cautiously and moderately heating the fluorspar.

CALOMEL. ($HgCl_2$ or $Hg = 85$; $Cl = 15$. *Syn.* Horn Quicksilver; Chloride of Mercury.)

Its crystals belong to the dimetric system, and are usually square prisms with four-sided pyramidal summits. The lateral edges make an angle of 135° 50′, and the terminal edges an angle of 98° 7′. The colour is dirty white or pale grey, but yellow where scratched; the lustre is adamantine; the fracture conchoidal; the sp. gr. 6·48 (72,433); and the hardness 1 to 2. It is transparent, or translucent; very fragile, yet easily cut; and possesses a high refractive power. It is entirely volatilised by the blowpipe, and is almost insoluble in water. It is found in small quantities crystallised, and in mammillated masses, associated with cinnabar, at Moschel-Landsberg in the Palatinate, Idria, Almaden, and Horsowitz.

COTUNNITE. ($PbCl_2$ or $Pb = 74$; $Cl = 26$.)

It crystallises in right rhombic prisms belonging to the trimetric system, and with an angle of 118° 38′. It is white, with a silky or pearly lustre, and a sp. gr. of 5·24 (58,570). It is easily scratched by the nail; is readily fused by the blowpipe, the flame of which it tinges blue;

and is slightly soluble in water and acids. It is a rare mineral, and was found in the crater of Vesuvius after the eruption of 1822, associated with chloride of sodium, the oxychloride (atacamite) and sulphate of copper.

Yttrocerite.

This appears to be a fluorspar containing cerium and yttrium. It is very rare, and has been found only in masses with rectangular cleavages, pointing to the cube as the principal crystalline form. It is of a bluish or greyish colour, and infusible before the blowpipe, which deprives it of its colour, thereby rendering it white. The pegmatites of Finbo and Broddbo in Sweden, and Amity, Orange Co., U.S., are the only localities for it.

Fluellite

A rare fluoride of aluminium found at Stenna-gyn, Cornwall, in acute rhombic octahedral crystals, associated with wavellite and uranite. It is white, transparent, and has a hardness of 3.

Chiolite.

This is regarded as a mixture of the fluoride of sodium with fluoride of aluminium. It belongs to the dimetric system, crystallising in minute, snow-white, translucent octahedrons, with a square base, modified summits, and a basal angle of 113° 25′. It is also found in granular masses with a crystalline structure, resembling the cryolite of Greenland. The hardness is 4, and the sp. gr. varies from 2·7 to 3. It fuses more readily than cryolite into a limpid globule, which becomes white on cooling. It gives the ordinary blowpipe reactions of fluorine. It occurs in granite at Miask, in the Ural Mountains, associated with fluorspar, topaz, phenacite, and cryolite.

Cryolite. (3 NaF. Al_2F_3 or F = 54·8; Na 32·7; Al = 12·5.)

A fluoride of sodium and aluminium met with in laminar masses, which cleave in three directions, but more readily

in one than in the two others. The general form of the crystals and their optical character make it probable that they belong to the monoclinic system. It is superficially of a white colour, occasionally tinged yellowish or reddish by the oxide of iron; but in the deeper parts it is almost black. When the black part is exposed to a red heat it becomes white, like the superficial cryolite. The sp. gr. is 2·9 or 3 (33,434), and the hardness 2·5. It melts with great facility, and resembles chiolite in its behaviour before the blowpipe. Sulphuric acid decomposes it, with disengagement of hydrofluoric acid; and nitric acid, when heated, dissolves it, forming a solution which yields a gelatinous precipitate with ammonia. It forms thick layers, bounded by thin seams of mica, in gneiss, at Evigtok, in the Arksut Fjord, Greenland, associated with hydrated oxide of iron, iron pyrites, copper pyrites, galena, quartz, and felspar; and in the Ural Mountains, associated with chiolite, lithia mica, and fluorspar. It is largely used as an aluminium ore, and as a source of soda.

There are several minerals which are either varieties of or closely related to cryolite, and found in the same localities. *Arksutite* is a variety containing lime; *pachnolite*, *thomsenolite*, and *gearksutite* are hydrated lime cryolites.

Melanothallite.

A chloride of copper discovered by Scacchi in the products from the eruption of Vesuvius in 1870.

Nantoquite. (Cu Cl.)

A chloride of copper occurring in masses, with cubic cleavage, indicative of its belonging to the isometric system of crystallisation. Hardness 2—2·5; sp. gr. 3·95; colourless; lustre adamantine. When fused on charcoal it colours the blowpipe flame an intense azure blue, and yields a ductile globule of copper. It readily dissolves in nitric and hydrochloric acids, and in ammonia. In the mine the workmen are much incon-

venienced by a strong odour of chlorine, which Domeyko states is due to the production of ozone, which accompanies the oxidation of the mineral.

Chloromagnesite.

A chloride of magnesium, which appears to have a composition corresponding to $Mg\ Cl_2 + 6\ H_2O$. Scacchi found it at Vesuvius during the eruption of 1872. A mineral which appears to be the same has been found by Ochsenius and Pfeiffer at Leopoldshall, in Prussia, and named by them Bischofite. This occurs in crystalline, granular, and foliated masses, having the fibres arranged transversely. Hardness 1—2; sp. gr. 1·65; colourless when pure; lustre vitreous to dull. It is soluble in rather more than half its own weight of water. It readily takes up water from the air, so that when the layer is exposed it rapidly passes into a higher state of hydration. The salt has been formed artificially, and crystallises in the monoclinic system. It forms layers more than an inch thick in rock salt, the associated minerals being kieserite and carnallite

Chlorocalcite.

An impure chloride of calcium, found in Guy's Cliff, Warwickshire, has been thus named. It is also reported from various localities in Peru.

Chloralluminite.

The name given by Scacchi to the hydrated chloride of aluminium found by him amongst the productions of the eruption of Vesuvius in 1872.

Sellaite.

This is considered to be a fluoride of magnesium (Mg Fl), analogous to fluorspar. It crystallises in dimetric crystals. Hardness 5; sp. gr. 2·97; lustre vitreous; fracture conchoidal; transparent and colourless. Small fragments melt in the flame of a candle with intumescence. Water and most acids do not dissolve it, but concentrated sulphuric acid does so, and

gives rise to an evolution of hydrofluoric acid. It is found with anhydrite at Geibroula, in Piedmont.

Proidonite.

A fluoride of silicon ($Si F_4$), observed by Scacchi in the exhalations from Vesuvius during the eruption in 1872.

Ralstonite.

A hydrated fluoride of aluminium, occurring in isometric octahedral crystals. Hardness 4·5; sp. gr. 2·4. When heated in a close tube, it yields water with acid reactions, and then a copious white sublimate, which etches the tube. With cobalt solution gives a deep blue. With salt of phosphorus the blowpipe flame reduces it to a colourless glass; when heated with carbonate of soda it decomposes with effervescence. Sulphuric acid decomposes it, and gives rise to hydrofluoric acid. It is associated with cryolite in Greenland.

CHAPTER VI.

Oxides.

Cuprite. (Cu_2O or Cu = 88·8; O = 11·2. *Syn.* Zigueline; Ruby Copper.)

It crystallises in the regular system, the prevailing form being the octahedron and the rhombododecahedron. The crystals are usually collected in drusy cavities. The colour is red, but of a different tint according as the specimens are looked at or looked through. The powder has a brick-red tint. The lustre is adamantine or sub-metallic, and on the fresh fracture, which is conchoidal, it is slightly vitreous; the sp. gr. is 5·8 (64,832) to 6·1 (68,185); and the hardness 3·5 or 4. On being heated before the blowpipe it fuses into a black mass, tinges the flame green, and ultimately yields a globule of copper. When reduced with borax it yields a colourless glass, which becomes

brick-red on cooling; and when subjected to the outer flame it yields an emerald-green glass, in consequence of the oxidation of the metal. With nitric acid it forms a green solution, which is turned blue by the addition of ammonia.

It is generally associated with copper, carbonates of copper (malachite and azurite), and sulphides of copper (copper glance and copper pyrites), in veins traversing granite, and the older crystalline schists and sedimentary deposits. It is found at several places in Cornwall, at Chessy and elsewhere in France, in Hungary, the Ural and Altai Mountains, in South Australia, and in various parts of North and South America.

Chalcotrichite, or capillary red oxide of copper, is a variety which occurs in bright red capillary needles belonging to the trimetric system, and having a rhombohedral cleavage. It is found at Nischne Tagilsk with limonite for a gangue; at Rheinbreitenbach, in crystals resting on quartz; at Moldavia, in Hungary; and at Huel Gorland and Tol Carn, in Cornwall.

PERICLASE. (MgO or Mg = 60; O = 40.)

Native magnesia is found in small octahedral crystals with cubic cleavage in the dolomite of Mont Somma, Vesuvius. It is transparent, and of a greenish tint, probably due to the oxide of iron found in it; its sp. gr. is 3·75 (41,816), and its hardness 6. It is infusible by the blowpipe, and forms a solution with nitric acid, from which a white powder is precipitated by ammonia. It is sometimes associated with white olivine and earthy magnesite. It has been produced artificially by igniting magnesia and ferric oxide in hydrochloric acid gas. Ordinary magnesia has a sp. ht. of ·243, and a sp. gr. of 3·07, which is increased to 3·6 when it has been ignited in a pottery furnace.

SPARTALITE. (ZnO or Zn = 80·26; O = 19·74.
Syn. Red Oxide of Zinc.)

The crystalline form of this species has not been clearly

made out, but the prevalent opinion seems to be in favour of its belonging to the hexagonal system. It is of a bright orange-red colour, translucent on the edges, and breaks with a conchoidal fracture. The sp. gr. is 5·4 (60,361); sp. ht. ·124; the hardness 4 to 4·5; and the lustre adamantine. It dissolves in nitric acid with effervescence, and is fused by the blowpipe into a yellow transparent glass when mixed with borax, but is infusible alone. All the specimens hitherto analysed have contained more or less oxide of manganese, from which its colour is probably derived. It occurs in small flakes amongst crystals of franklinite at Franklin, Sparta, and Sterling, in New Jersey Co., United States.

MELACONITE. (Cu_2O_2 or Cu = 80; O = 20. *Syn.* Black Copper; Tenorite.)

It is found in cubes at Keweenaw Point, Lake Superior, which are supposed by some to be pseudomorphs after cuprite; but this opinion is opposed by Whitney, who draws attention to the fact that the associated crystals of cuprite are always in octahedrons, never in cubes. It has also been found in thin scales in the Vesuvian lavas, and in soft, easily pulverisable masses. The crystals have a dark steel-grey colour, but the powder is almost black. Artificial crystals found in the hearth of a furnace at Freiberg were of an iron-black colour, belonged to the trimetric system, and had a sp. gr. of 6·45 (72,098). The native crystals have a sp. gr. of 6·25 (Whitney); 5·95 (Rammelsberg).

LEAD OCHRE. (PbO or Pb = 92·9; O = 7·1. *Syn.* Massicot; Yellow Oxide of Lead; Native Litharge.)

This is a yellowish mineral, found in scaly crystalline lumps, associated with native lead and galena, in the neighbourhood of Zomalohuacan, near the volcano of Popocatapetl, and a few other localities in Mexico; as also in Virginia. It is soft, and has a sp. gr. of 8·0 (89,424); and a sp. ht. of ·055.

BRUCITE. ($MgO.\ H_2O$ or $MgO = 69{\cdot}5$; $H_2O = 30{\cdot}5$. *Syn.* Nemalite; Lancasterite; Hydrate of Magnesia.)

It crystallises in rhombohedral forms, such as hexagonal tables with a marked basal cleavage, and fibrous masses. According to Dana the primary form is a rhombohedron with an angle of 82° 15′. It is usually white, but sometimes has a greenish or greyish tinge. It has a hardness of 1·5; a sp. gr. of 2·35 (26,248); a sp. ht. of ·312; and a pearly lustre. It is flexible in thin laminæ; is infusible by itself; and soluble in acids without effervescence. This last character distinguishes it from lamellar transparent gypsum. It occurs in serpentine, along with other magnesian minerals, at Hoboken, New Jersey; in New York State; Texas; Pennsylvania; in the Isle of Unst; at Pyschminsk, near Beresof, in the Ural Mountains; and at Goujot, in France; also in limestone near Filipstadt-Wermeland.

Nemalite is a ferruginous fibrous variety found at Hoboken.

MENDIPITE. ($Pb_3Cl_4O_2$ or $PbCl_2 = 38{\cdot}4 + 2\ PbO = 61{\cdot}6$. *Syn.* Berzelite; Cerusite.)

It forms trimetric prismatic crystals of a yellowish or light rose colour. When pure the crystals are translucent, and with a pearly lustre on the cleavage faces. It is also met with in bacillar compact masses. The hardness is 2·5 or 3; and the sp. gr. 7 (78,246) or 7·1. It is readily fusible by the blowpipe. It was first found at Churchill, in the Mendip Hills, Somersetshire, and has since been obtained at Brillon, in Westphalia; and Tarnowitz, in Silesia.

MATLOCKITE. (Pb_2Cl_2O or $PbCl_2 + PbO$.)

Found in dimetric tabular crystals in an old mine at Cromford, near Matlock, which had a yellowish or greenish colour, an adamantine lustre, sometimes inclined to pearly, a sp. gr. of 7·2 (80,481), and a hardness of 2·5. It decrepitates when heated, melts before the blowpipe

into a greyish-yellow globule, and is soluble in nitric acid.

VOLTZITE. (Zn_5SO.)

An oxysulphide of zinc, found in spheroidal masses, with a concentric structure, and a slightly pearly lustre. It has a brick-red or brownish colour; a sp. gr. of 3·6 (40,140); and a hardness of 4·5. It resembles blende in its behaviour before the blowpipe. It was discovered near Pontgibaud, in the department of Puy de Dôme, France; and is also found at Joachimsthal, associated with blende; in Cornwall; and at Bern Kastel. Kersten has noticed its presence in furnace products.

ATACAMITE. (*Syn.* Smaragdocalcite; Remolinite; Chloride of Copper.)

The analyses differ in the quantity of water it contains, but the formula usually assigned to it is $CuCl_2 + 3\,Cu\,O + 3\,H_2O$. Some specimens contain $4\frac{1}{2}$ parts, and others 6 parts of water. It is a native hydrated oxychloride of copper, crystallising in prismatic needles or rhombic prisms. It is of a beautiful emerald-green or bluish-green colour, and forms a green sand in the desert of Atacama, Bolivia. It has also been found in some of the Peruvian and Chilian silver mines; in the mines of Schwarzenberg, Saxony; and at Serra da Bembe, near Ambriz, on the west coast of Africa. It is said to have been found in the lavas of Vesuvius, but this supposed atacamite is sulphate of copper, according to Scacchi. It is sometimes formed by the action of air and sea-water on copper and bronze; and is occasionally met with in the rust on old coins and statues. The Indians of Peru form a powder from atacamite for drying moist writing, and sell it under the name of *arenilla*.

MAGNETITE. (Fe_3O_4 or $FeO.\,Fe_2O_3$. *Syn.* Oxydulous Iron; Octahedral Iron; Magnetic Iron Ore.)

It crystallises in the regular system, the prevailing forms being the octahedron, the dodecahedron, and modi-

fications of them. (Figs. 5, 9, 10, Pl. I.) The cleavage is octahedral, and the faces of the rhombohedron are frequently striated in the direction of the longer diagonal. The ore is of a brilliant iron black, but the powder is jet black. Its density is 4·8 (53,654) to 5 (55,890); its sp. ht. ·166; and its hardness is 5·5 to 6·5. It is strongly attracted by the magnet, and some of the compact specimens are themselves highly magnetic. These latter form the natural lodestones. It is with difficulty fused by the blowpipe, and is soluble in hot hydrochloric acid, but not in nitric acid. This mineral is a combination of the protoxide and sesquioxide of iron; the former is frequently replaced to a certain extent by the isomorphous protoxides of magnesium and manganese; while the latter may be partially replaced by titanic acid, forming the titaniferous iron ore.

Magnetite is very abundant, but Norway, Sweden, Lapland, and Siberia contain the most important deposits. It is also met with in France, Italy, Brazil, and North Scotland. In England it occurs at Rosedale in Yorkshire, and in the western counties. Its usual geological position is in the most highly metamorphic rocks, in which it probably represents the excess of iron oxide originally in the rock, which was not taken up by silica. It is sometimes in layers, but in Norway, Sweden, North America, and elsewhere, it forms whole mountains. Among other rocks in which it occurs, the following are the most important; viz., crystalline limestone; chloritic, talcose, hornblendic, pyroxenic and hypersthenic schists; serpentine, diorite, and basalt. Specular iron is frequently associated with it.

SPINEL. (Al_2O_3. MgO or Al_2MgO_4. *Syn.* Spinel Ruby; Balas Ruby.)

An aluminate of magnesia, crystallising in the regular system, the predominating form being the octahedron; it has also been found in rhombododecahedrons, but not in cubes. Its hardness is 8, so that it ranks amongst the hardest minerals, and indeed few others, such as the

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diamond, corundum, and the sapphire, will scratch it; the sp. gr. ranges from 3·5 (39,023) to 3·8 (42,376); the sp. ht. is ·194; and the lustre is lively and vitreous. The purest specimens are colourless, but spinel is usually coloured various shades of red, blue, green, or black by the presence of chromic acid and other substances. It is infusible before the blowpipe, but when highly heated the colour changes; and it is not affected by acids. Both the alumina and magnesia are replaced to a greater or less extent by their isomorphs, which are chromic and ferric acids in the case of the alumina, and the protoxides of iron, manganese, and zinc in the case of magnesia. By such replacements we obtain a number of varieties. Thus, there is the red or rosy variety, which jewellers call *spinel* when the colour approaches to scarlet; *balas ruby* when the tint is somewhat lighter; and *rubicelle* when there is a slight dash of orange. These probably owe their colour to the chromic acid which they contain. They occur in association with the oriental ruby and sapphire in the crystalline rocks, such as granite, gneiss, mica schist, granular marbles, and saccharoidal dolomite; they also occur in sands derived from the destruction of these rocks, as, for instance, near Candy, in Ceylon, from whence the finest specimens are procured. There are other localities in Birmah, Pegu, and North America. Small crystals have been obtained from the tin streams of Bretagne. The *balas* rubies are rose-red spinels, from Badakhshan or Balakshan, in Central Asia, where it occurs in nodules in a magnesian limestone. The mines are not worked now, in consequence of the small profits which were obtained.

The pale bluish and greyish varieties contain from 3 to 4 per cent. of protoxide of iron, and occur in similar crystalline rocks to those just mentioned. In green spinel, or *chlorospinel*, the alumina has been partially replaced by ferric acid, which has united with the magnesia to form magno-ferrite (or ferrate of magnesia). It is found in talcose schists at Slatoust, Siberia; in granular limestone at Ersby, Finland; and at a few localities in

the United States. *Dysluite* is a pale yellowish impure variety from limestone, New Jersey, which has a hardness of 4·5 only, and a sp. gr. of 4·5. *Pleonaste, Ceylonite,* and *Candite* are names given to the black spinel, containing a large proportion of iron oxides; it is found in small black brilliant octahedral crystals in some of the blocks ejected from Vesuvius.

Spinel has been crystallised artificially by Ebelmen.

Automolite, or *Automalite* (gahnite), is a zinc spinel in which zinc oxide predominates over the magnesia. Its sp. gr. varies from 4·1 (45,829) to 4·6 (51,418); its hardness is 8; its lustre vitreous; and its colour dark green. It has been found in talcose schist in Sweden; in New Jersey; in Pisgah mine, at Tennessee; and in Canton mine, Savannah.

CHROMITE. (*Syn.* Chrome Iron Ore; Chromic Iron; Chromate of Iron.)

The analyses of this mineral always indicate that the specimens resemble spinel in their chemical constitution, and that they are made up of variable proportions of certain isomorphous substances. If pure, it would probably be represented by the formula, $FeOCr_2O_3$ or $FeCr_2O_4$; but the protoxide of iron is nearly always more or less replaced by its isomorphs, the protoxides of chromium, nickel, and magnesia; while the sesquioxide of chromium is more or less replaced by sesquioxide of iron and alumina. In any case it may be represented by the general formula for the spinel group; viz., $DO.R_2O_3$.

It crystallises in the cubic system, the prevailing form being the regular octahedron, with octahedral cleavage. In colour it is iron or brownish black; the powder is brown; the fracture uneven and imperfectly conchoidal; the lustre sub-metallic, and more or less waxy; the sp. ht. ·159; the sp. gr. 4·3 (48,055) to 4·5 (50,301); and the hardness 5·5. Occasionally it is slightly magnetic, and when heated with the blowpipe-flame becomes more strongly so.

It is infusible by itself, but is fused with difficulty with

borax or phosphorus salt, yielding an emerald-green glass. It occurs in serpentines, or in sands derived from serpentines, generally in grains or nodular lumps. It is much sought after as a source of chromic acid, which is used in the manufacture of chrome yellow or chromate of lead. The principal localities from whence it is obtained are in the Shetland Islands, Norway, and Maryland, United States; but it is also met with in France, Tuscany, Silesia, Siberia, Styria, Syria, Pennsylvania, and San Domingo.

FRANKLINITE. ($3\,\overbrace{Zn : FeO}.\ \overbrace{Mn_2 : Fe_2O_3}.$)

This is generally considered to belong to the spinel group of minerals; but Rammelsberg and others consider the above formula as erroneous. The mineral is a combination of the sesquioxides of iron and manganese with the protoxides of zinc and iron, and crystallises in the regular system, the prevailing form being the octahedron, with indistinct octahedral cleavage; but it also occurs in several other compound forms of this system. In the mass it has an iron-black colour; but in powder it has a dark brownish-red tint. It is brittle, breaks with a conchoidal fracture, has a hardness varying from 5·5 to 6·5, and possesses a sp. gr. of 5·1 (57,007). It is feebly attracted by the magnet. It is not fusible by the blowpipe; but when heated in the reduction flame with soda it yields oxide of zinc, and when heated with borax it gives the reaction of manganese.

Franklinite belongs essentially to the metamorphic rocks. Thus at Franklin, New Jersey, it occurs in granular limestone, associated with red oxide of zinc, automolite, and willemite; and at Stirling, in the same State, it is associated with red oxide of zinc in a crystalline silurian limestone: at both these localities it forms fine crystals. It is said to be met with in amorphous masses in the zinc mine near Aix-la-Chapelle.

PITCHBLENDE. (*Syn.* Oxydulated Uranium.)

It is a mineral composed of a mixture of the protoxide

and sesquioxide of uranium ($UO.\ U_2O_3$), but as it is seldom found in a pure state, its properties vary considerably. It occurs in semi-crystalline masses of a brownish-black colour, with a semi-metallic lustre, a hardness of 5·6, and a sp. gr. of 4·8 (53,654) to 6·5 (72,667). It is infusible before the blowpipe, colours the flame green, and when heated in the outer flame along with borax, yields a yellow glass. It has been found in argentiferous veins in Saxony and Bohemia, in the tin mines of Cornwall, and at Stromsheien, Norway. *Eliasite* is called pitchblende; it is probably a hydrated uranic oxide ($U_2O_3.\ H_2O$), mixed with alumina, lime, magnesia, silica, phosphoric acid, carbonic acid, and arsenic.

HAUSMANNITE. ($MnO.\ Mn_2O_3$. *Syn.* Red Oxide of Manganese; Black Manganese Ore.)

This is a compound of manganous and manganic oxides, analogous to magnetite, which is a compound of ferrous and ferric oxides. The crystals are acute quadratic pyramids, in which the lateral edges form an angle of 117° 54′, and have a nearly perfect basal cleavage; they frequently form twins and groups of four. It has a brownish-black colour in the mass, and a chestnut-brown one in powder. It is opaque, breaks with an uneven fracture, and has a sub-metallic lustre. Its sp. gr. is 4·8 (53,654), and its hardness is 5·5 The heat of the blowpipe neither melts nor alters it. It may be produced artificially by intensely heating any of the other oxides of manganese in the presence of air, and also by exposing metallic manganese to moist air at ordinary temperatures, but more rapidly at higher temperatures. It occurs in crystals and compact masses, associated with *braunite* and other manganese ores, in the porphyry near Ilmenau in Thuringia, and near Ihlefield in the Harz.

CHRYSOBERYL. ($GlO.\ Al_2O_3$. *Syn.* Cymophane; Oriental Chrysolite; Alexandrite.)

It is a compound of alumina and glucina, and crystallises in right rhombic prisms belonging to the trimetric

system. Its colour is bluish or yellowish green by reflected, and sometimes reddish by transmitted, light. Its lustre is vitreous; sp. gr. 3·5 (39,023) to 3·8 (42,376); and hardness 8·5. This last-mentioned property distinguishes it from topaz; while its crystalline form distinguishes it from euclase and the beryl. It has a conchoidal uneven fracture, exhibits double refraction, is rendered electric by heat, is infusible alone before the blowpipe, and is insoluble in acids. It occurs in scattered crystals and grains in granites, gneiss, and mica schist, and in sands derived from their destruction. In the sands of Ceylon and Borneo it is associated with spinel and tourmaline; and in those of Brazil with topaz and the diamond. It is associated with fibrolite and garnet in the gneiss of Moravia; with beryl, tourmaline, and garnet in the pegmatite at Saratoga, New York; with beryl and phenacite in the emerald mines of Takowaja, Siberia; and it was formerly found with beryl, tourmaline, and garnet in granite at Haddam, Connecticut. The specimens from Siberia are of an emerald-green colour, and form the variety named *Alexandrite*. This colour is attributed to the presence of chromic acid; this variety is, however, further remarkable for exhibiting trichroism. Thus it is emerald-green by reflected light, columbine red when viewed by transmitted light in the direction of the short diagonal, and orange yellow by transmitted light in the direction of the long diagonal.

MINIUM. ($PbO.Pb_2O_3$ or Pb_3O_4. *Syn.* Red Lead; Red Oxide of Lead.)

It occurs as a red powder encrusting various lead ores, especially galena, and is probably the result of their oxidation. It has been found at Grassington Moor and Weardale, in Yorkshire; in the Isle of Anglesey; at Brillon, in Westphalia; at Badenweiler, in Baden; at Bleialf and Kall, in the Eifel; and in Virginia. It has been formed artificially by exposing the protoxide of lead, heated to redness, to air. Its specific gravity is 8·6 (96,130). According to Dana, Bristow, and others, the specific gravity of the native minium is 4·6 only.

BRAUNITE. (Mn_2O_3 or Mn = 70; O = 30.)

This is the native manganic oxide, which usually occurs in minute crystals aggregated together in druses. The crystals are obtuse quadratic pyramids, closely resembling the regular octahedron, in which the angle of the terminal edges is 109° 53′, and of the lateral edges 108° 39′, or modifications of them. In the pure varieties there is a distinct cleavage parallel to the faces of the pyramid; but in *marceline*, which is a variety containing silica, there are no signs of this cleavage. The crystals and powder of braunite have a dark brownish-black powder; the lustre is sub-metallic; the specific gravity 4·75 (53,095) in marceline, but 4·82 (53,897) in purer specimens; and the hardness 6·5. It is infusible before the blowpipe, but if the heat is intense, a portion of the oxygen is driven off, and the manganoso-manganic oxide is formed. It exists in small veins in porphyritic rocks at Vizianagram, India; Elba, Eglersberg and Oehrenstock, near Ilmenau, in Thuringia; Ihlefield, in the Harz; and at Vermont, U.S. *Marceline* occurs at St. Marcel, in Piedmont, associated with hyaline quartz, violet epidote and tremolite, and greenowite.

CORUNDUM. (Al_2O_3 or Al = 53·27; O = 46·73.)

This mineral consists simply of alumina, which in its crystalline state is remarkable for hardness and durability. It is generally mixed with minute quantities of other oxides, which impart to it certain colours. Its crystals belong to the hexagonal system, and are nearly isomorphous with those of ferric, chromic, and titanic oxides. They are derivable from an acute rhombohedron, with the angle of the lateral edges equal to 86° 6′, with distinct cleavage parallel to the faces of this rhombohedron. The prevalent forms of crystal are the hexagonal prisms and double pyramids with hexagonal bases. It also occurs in massive lumps and in a fine powder. When pure it is colourless and transparent, and has a vitreous lustre; but in the varieties it is white, grey, blue, red, violet, yellow, and brown, and in some cases the lustre is

somewhat pearly. The specific gravity is 3·9 to 4, and the hardness is 9, which is greater than that of all other substances, with the exception of the diamond. The fracture is conchoidal or splintery. It is unalterable, and infusible by the ordinary blowpipe, but it may be fused with the aid of the oxyhydrogen flame; no acid at ordinary temperatures will dissolve it in the crystalline state, but the powder is soluble in strong hydrochloric and sulphuric acids. It is, however, readily fused when mixed with sulphate of potash, and may be dissolved in liquid boracic acid at high temperatures. Artificial crystals have been obtained in various ways, such as precipitating it from its solution in boracic acid, and fusing it with alum, and driving off the alum. By the addition of a little chromate of potassium, crystals having the form and colour of the ruby have been obtained.

The varieties which are most translucent, and possess a decidedly vitreous lustre, are ranked as precious stones. The most distinguished are the *sapphire*, which is blue; the *ruby*, which is red; the *topaz*, which is yellow; the *amethyst*, which is violet. They are sometimes distinguished from other minerals bearing similar names by the prefix *oriental*. Some of these varieties present variations in their behaviour towards light. Thus, some are dichroic; others show milky-white reflections; and others exhibit an opalescent six-rayed star, with the rays at right angles to the vertical axis, whence they are termed *asterias*.

Fig. 34.

The varieties which present little or no translucency, break with a splintery fracture, easily divide into rhomboidal fragments, possess colours more or less tarnished, and are the most easily cleavable, are designated as *corundum*, *common corundum*, and *adamantine corundum* (Fig. 34). Those which are opaque, earthy in aspect, dark grey in colour, are called *compact corundum*. The variety which possesses a finely granular texture, brownish colour, and contains ferric oxide, is emery, so well known

for its use in polishing fine stones, glass, and metals. According to Dr. Jackson, ferrous oxide is an essential constituent in the emery of Naxos and of South Mountain, in Chester, Massachusetts. His analyses indicate the composition to be $FeO.Al_2O_3$.

Corundum is found in the most highly crystalline rocks, such as granites, syenites, gneiss, mica schist, and granular limestone. The transparent varieties occur in granitic rocks in India, China, Thibet, the Ural Mountains, in Central France, and in the United States. They are generally disseminated through the rocks, and are usually obtained from the sands derived from them. Compact corundum is met with in felspathic rocks at Mozzo, Piedmont; Miask, Siberia; Gellivara, Sweden; and other localities. Clear blue and rose crystals exist in saccharoidal dolomite at St. Gothard. Emery is associated with similar rocks, occurring in mica schist in Saxony; in granular limestones and dolomites in Naxos, and other Grecian isles; and in granite at Gumuch-Dagh, near Ephesus.

By the absorption of water corundum sometimes passes into diaspore.

HÆMATITE. (Fe_2O_3 or $Fe = 69{\cdot}34$; $O = 30{\cdot}66$. *Syn.* Specular Iron; Red Hæmatite; Red Ironstone; Iron Glance; Martite; Fer Oligiste.)

With the same chemical constitution as corundum, hæmatite closely resembles that mineral in its crystalline form. The crystals are derivable from a rhombohedron, with the angle of the lateral edges equal to 86°, and with indistinct cleavage parallel to the faces of the rhombohedron. The prevailing forms are rhombohedrons, double pyramids with six faces, and hexagonal prisms. Some of the latter are thin tables with oblique edges. The colour of the crystals is dark steel-grey, or, when slightly decomposed, iridescent; but that of the powder and the lithoid varieties is a dark red or blood-red, whence is derived the name hæmatite. The lustre of the crystals is splendent metallic, but the compact and earthy varieties have little

or no lustre. The specific gravity also varies considerably, ranging from 4·2 (46,947) to 5·3 (59,233); the specific heat averages ·157; and the hardness ranges from 5·5 to 6·5. It is sometimes slightly magnetic, probably in consequence of containing ferrous oxide. It is not fusible, but when strongly heated a portion of the oxygen is given off, leaving a residue, consisting mainly of ferroso-ferric oxide, which is the magnetic oxide. When exposed along with combustible bodies, it readily gives up its oxygen, both at high and at ordinary temperatures; hence, when left in contact with organic matter, it becomes converted into the magnetic oxide, or even to ferrous oxide, which, taking up carbonic acid, may become spathic iron. If the ferrous oxide is moist, it is readily oxidised by the atmosphere, and yields limonite, or the hydrated ferric oxide. Hæmatite is soluble in the acids, but most readily in strong boiling hydrochloric acid.

There are a great many varieties of hæmatite; the more important are *specular iron* or *iron glance*, a name by which the more crystalline states are designated.

Red hæmatite is opaque, blood-red, and without any metallic lustre. It usually occurs in nodules, having a fine radiated structure. *Red ironstone* is earthy, compact, and nearly pure. *Red ochre* and *red chalk* are less compact, and contain more or less clay. Some *clay ironstones* contain a considerable proportion of hæmatite. *Iron mica*, or *micaceous iron*, is a variety occurring in large schistose masses composed of thin scales, which sometimes present undulations like those of mica schist. It is characteristic of the rock known as *itabirite*. Hæmatite frequently occurs in other than rhombohedral forms, such as the cube, the regular octahedron, and the rhombic prism; but they arise from the decomposition of minerals crystallising in these forms into hæmatite. The octahedral variety is termed *martite*, but, according to some mineralogists, this is a second crystalline form of hæmatite, and, consequently, a distinct species; and, according to others, it is a pseudomorph after magnetite.

Hæmatite is one of the commonest and most widely

distributed of minerals; but the red lithoid varieties are far more abundant than the grey crystalline varieties; the ochreous iron occurs in nearly all the reddish mineral masses, such as red marls, sands, sandstones, and clays; the red hæmatite, especially the fibrous varieties, abound more particularly in the stratified deposits; while the crystalline varieties are usually met with in the crystalline rocks. It sometimes constitutes vast masses, the principal of which are those at Langbanshytta, in Sweden; Krageroe, in Norway; Gellivara, in Lapland; in the Isle of Elba; Picton Nob, in North America; and in Brazil. The iron mine of Elba is celebrated for the length of time which it has been worked. Virgil and Strabo allude to it as having been long known in their day; and although it has been worked for twenty centuries, it still yields abundance of metal. Hæmatite exists in so many countries, and in so many rocks, that we cannot attempt to give any account of its lithological and geographical distribution.

ILMENITE. *Syn.* Crichtonite; Menaccanite; Titaniferous Iron; Washingtonite; Hystatite; Mohsite; Iserine and Nigrine in part.)

This is probably a mixture of ferric, ferrous, and titanic oxides. Its crystals are probably derived from a rhombohedron with a lateral angle of 86° 6′, and, if so, are isomorphous with those of hæmatite and corundum. The prevailing forms are very acute rhombohedrons; tabular plates like those of hæmatite; and short thick crystals like those of hæmatite at Elba. The colour is iron or bluish black, and the powder is blackish, with an occasional tinge of brownish-red. The lustre is submetallic, the hardness 5 to 6, the sp. ht. ·177, and the sp. gr. 4·6 (51,418) to 5·2 (58,126). It is infusible before the blowpipe, and dissolves in hydrochloric acid with precipitation of titanic acid (TiO_2).

It is common in the sands of many streams, forming the titaniferous iron sand; and is also met with in nodules, and lumps, and crystals in the granitic rocks of

the Alps, associated with hyaline quartz, axinite, anatase, and chlorite; in miascite, a granite rock at Miask, Siberia, associated with mica, felspar, pyrochlore, elæolite; in the zircon syenite of Norway, associated with albite, garnet, magnetite, &c.; and under similar circumstances in numerous other localities.

CREDNERITE. ($3\,CuO_2 . 2\,Mn_2O_3$ or $CuO = 42{\cdot}85$; $Mn_2O_3 = 57{\cdot}15$. *Syn.* Copper or Cupriferous Manganese.)

It occurs in masses, having a crystallo-laminar structure, and cleaving in two directions parallel to the sides of a monoclinic prism, the more distinct of the two being parallel to the base. It has an iron-black or steel-grey colour; an uneven fracture; a metallic lustre, which is most marked on the basal cleavage face; a sp. gr. of 4·9 (54,772) to 5·1 (57,007), and a hardness of 4·0 to 4·5. It is slightly fusible in thin laminæ; forms a dark violet glass with borax; and a blue one, when cold, with phosphorus salt. It dissolves in hydrochloric acid with evolution of chlorine, yielding a green solution. It is found at Friedrichsrode, in the Thuringerwald, associated with various manganese minerals, such as hausmannite and psilomelane; and also with various copper minerals, such as malachite and volborthite.

DIASPORE. ($Al_2O_3 . H_2O$ or $Al_2O_3 = 85$; $H_2O = 15$. *Syn.* Laminated Hydrargillite; Stephanite.)

This is a native monohydrate of alumina, which crystallises in right rhombic prisms, whose vertical faces are inclined to each other at an angle of about 130°. The cleavage is most distinct, parallel to the short diagonal of the base. The crystals are usually flat acicular prisms, somewhat similar to those of kyanite and zoisite. The colour is yellowish-brown in some specimens, and a greenish-white in others; the lustre is pearly or vitreous; the sp. gr. varies from 3·3 (36,777) to 3·6 (40,140), and the hardness from 6·5 to 7. It is infusible by the blowpipe, but when heated it decrepitates and throws off whitened

splinters. If ignited when moistened with a solution of cobalt, it turns blue.

It is found in a felspathic rock at Broddbo, in Sweden: in chloritic schist containing emery at Gornoschil and Kassoibrod, in the Ural Mountains, associated with limonite; in dolomites containing corundum at Campo Longo, St. Gothard; in sands in Brazil containing corundum. According to some authorities the diaspore is derived from the emery and corundum by their combination with water; but according to others, the latter minerals are derived from the diaspore by the loss of water. Some of the white diaspore crystals from an argillaceous deposit at Schemnitz, Hungary, are remarkable for exhibiting trichroism—that is, for exhibiting three different colours when looked through in three different directions; thus they are reddish-blue in one direction, violet-blue in another, and green in a third.

HYDRARGILLITE. ($Al_2O_3 . 3 H_2O$ or $Al_2O_3 = 65{\cdot}5$; $H_2O = 34{\cdot}5$. *Syn.* Gibbsite; Felsobanyite.)

This is the trihydrate of alumina, which occurs in hexagonal prisms with distinct basal cleavage near Slatoust, in the Ural Mountains; but it is generally found in stalactitic, spherical, or hemispherical masses, having a radiated fibrous structure, somewhat resembling that of wavellite. It has a reddish-white colour, a considerable degree of translucency, a hardness of from 3 to 3·75, and a sp. gr. of 2·3 (25,699) or 2·4 (26,827). It is infusible by the blowpipe; but when heated it becomes white, decrepitates, and exfoliates. It is slightly soluble in hot, strong hydrochloric and sulphuric acids, and gives off the argillaceous odour when breathed upon. At the locality near Slatoust it is associated with magnetite and chlorospinel. It is also found at Gumuch-Dagh, Asia Minor; at Richmond, in Massachusetts, and one or two other North American localities.

GÖTHITE. ($Fe_2O_3 . H_2O$ or $Fe_2O_3 = 90$; $H_2O = 10$. *Syn.* Needle-iron Ore; Onegite; Ferric Monohydrate.)

Of all the native ferric hydrates this is the only one that

occurs crystallised. Its crystals belong to the trimetric system, and the prevailing form is a right rhombic prism of 94° 52′, while a modification of this is a prism whose vertical faces are inclined at an angle of 130° 57′. This latter is isomorphous with the crystals of diaspore, the monohydrate of alumina. There is a distinct cleavage parallel to the short diagonal of the base. The faces of the prism are longitudinally striated, and the crystals are frequently flattened in the direction of the short diagonal. The colour is yellowish, reddish, or blackish brown; or hyacinth-red in thin specimens and by transmitted light. The powder is brownish-yellow. The lustre approaches to adamantine. The sp. gr. is 4 (44,712) to 4·4 (49,183), and the hardness 5 to 5·5.

When calcined it turns red; when exposed to the blowpipe flame it melts, unless the reduction flame is employed, in which case it blackens, and becomes magnetite. It gives up part of its water below 212°, and all at a red heat. It is readily deoxidised by oxidisable bodies, such as putrefying organic matter; but it is oxidised in air. Hence, when mixed with such matter, with exclusion of air, it forms ferroso-ferric compounds; but when exposed to air, it is oxidised by it, and deoxidised by the organic matter, thus acting as a carrier of oxygen from the air to the organic matter. There are several varieties. *Göthite* proper occurs at Lake Onega, Siberia; at Clifton, near Bristol; Lostwithiel and Botallack, Cornwall; *rubinglimmer* occurs with brown hæmatite at Eisenfield, Nassau, and elsewhere; *lepidocrocite* in fibrous lumps at Sayn and Siegen, Rhenish Prussia; and *stilpnosiderite* in brownish-black masses in ferriferous veins in the Black Forest. It is a frequent pseudomorph after iron pyrites, and is constantly associated with limonite.

MANGANITE. ($Mn_2O_3 . H_2O$ or $Mn_2O_3 = 89·9$; $H_2O = 10·1$. *Syn.* Grey Manganese Ore; Hydrated Manganic Oxide.)

It belongs to the trimetric system of crystallisation, and occurs in right rhombic prisms, either simple or modified.

These are frequently long needles with longitudinally striated faces, and with the cleavage in the direction parallel to the long diagonal more perfect than the cleavage parallel to the short diagonal. It has a dark steel-grey or iron-black colour, a reddish-brown powder, a sub-metallic lustre, an uneven fracture, a sp. ht. of ·176, a sp. gr. of 4·2 (46,947) to 4·4 (49,183), and a hardness of 4. It is soluble in cold hydrochloric acid. In addition to the crystallised form there are numerous massive varieties, such as those having a mammillated, dendritic, stalactitic, oolitic, or scaly structure. *Wad* is an amorphous form of manganite; but this name is also applied to other amorphous oxides of manganese. Manganite is one of the most abundant of the manganese ores, and often accompanies *pyrolusite*. It forms considerable beds in the older crystalline rocks, and is frequently associated with hæmatite or with carbonate of iron. It has been found in various parts of France; in porphyry at Ihlefield, in the Harz; in Devonshire and Aberdeenshire; in Sweden, Norway, and Thuringia.

LIMONITE. ($2\,Fe_2O_3\,.\,3\,H_2O$ or $Fe_2O_3 = 85{\cdot}3$; $H_2O = 14{\cdot}5$. *Syn.* Brown Hæmatite; Morass Ore; Yellow Ochre.)

Its crystalline form is unknown, as it has only been found in earthy and friable masses, which sometimes have a fibrous structure. It resembles göthite in many of its properties, but may be distinguished from it by its lighter yellow colour and the larger proportion of water contained in it. It embraces a great many varieties, and is the usual iron ore met with in the sedimentary strata. It first begins to be abundant in the oolitic system, and may be found in almost every bed of the subsequent formations. It is formed by the action of alkaline carbonates on ferric salts, and of air on ferrous oxide and ferrous salts.

Brown hæmatite resembles red hæmatite in its fibrous structure, but differs in having a silky lustre and a brown-coloured powder. *Brown ironstone* is a compact variety.

Bog ore, or limonite proper, is almost entirely confined to the more recent strata, such as those belonging to the tertiary and post-tertiary formations. It usually occurs in low swampy grounds, boggy hollows, and the shallow parts of lakes. It is formed under somewhat similar circumstances as göthite. It is not abundant in Great Britain, except perhaps in the peat bogs of Ireland and Scotland, but exists in large quantities in many parts of the European and American continents. *Pea iron ore*, or *oolitic limonite*, occurs in connection with limestones having an oolitic structure. The colour is generally brown, but is sometimes blue, as at Hayanges, near Thionville, and sometimes greenish, as in the valley of Chamoison, near Ardon, in the Valais. The *pisolitic iron ore* is a limonite in small globular masses compressed together. Large beds of it occur in the Jura Mountains, and it is exceedingly abundant in many of the departments of Central France. Some of these varieties, but especially the last mentioned, are much used as a source of iron in Germany and France. *Yellow ochre* is a nearly pure limonite, and *umber* is a limonite containing a large proportion of manganite.

PSILOMELANE. (*Syn.* Barytiferous Oxide of Manganese.)

This is an amorphous hydrated manganese ore, probably a mixture of *braunite* and *groroilite*. It contains from 1 to 17 per cent. of baryta, has an iron-black colour, a brownish-black shining streak, a sub-metallic lustre, a sp. gr. of from 3·7 (41,258) to 4·3 (48,055), and a hardness of from 5 to 6. It is common in various parts of France, Germany, England, and other countries. Some of the varieties of psilomelane are occasionally called *wad*, a name applied to several hydrated oxides of manganese mixed with silica, alumina, lime, baryta, and other substances. *Earthy cobalt*, or *cobalt ochre*, may be regarded as a cobaltiferous wad. It is generally met with in association with cobalt and manganese ores. *Cupreous manganese* and *pelokonite* are wads which contain a large proportion of oxide of copper

CASSITERITE. (SnO_2 or Sn = 78·62; O = 21·38. *Syn.* Tinstone.)

It crystallises in forms which are modifications of a right rhombic prism, similar to that shown in Fig. 20, Pl. I. They are generally short prisms, with four or eight-sided pyramidal summits, or in still more complicated combinations, such as the twin-crystal represented in Fig. 35. It is transparent, rarely colourless, but usually a reddish-brown or brownish-black; sometimes, however, it is a clear grey or a hyacinth-red. It has an adamantine lustre on most of the faces, while that which shows a conchoidal fracture has a vitreous lustre. The sp. gr. is 6·8 (76,010); the sp. ht., ·0894; and the hardness 7, or sufficient to scratch glass. It is infusible in lumps before the blowpipe, but thin flakes may be melted; and it is slightly soluble in hydrochloric acid.

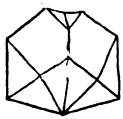

Fig. 35.

Cassiterite occurs as *stream tin* and *wood tin*, which represent its non-crystalline states. The former embraces the rolled, finely granular masses found in sands and sedimentary deposits; and the latter such as have a compact fibrous structure combined with a distribution of the colour in bands of light brown and dark yellowish tints. These appear to have been derived from the veins of cassiterite, which traverse such rocks as granite, gneiss, porphyry, and schists. These veins appear to be amongst the oldest metalliferous lodes in Cornwall, since they are never cut by those containing other metallic minerals. It is usually supposed that these tin lodes are older than any of the fossiliferous rocks, and that in every country they were formed before the veins containing other metallic ores. But there is no evidence to support these suppositions. On the contrary, it is known that the tin lodes of Cornwall were formed during the carboniferous era, while in Wexford similar lodes were formed long before, and yet after others containing lead and copper. The probability is, that metalliferous veins of every kind may be

referred to every geological period during which crystalline rocks were formed, and that their relative ages vary in different countries. The Cornish mines are by far the most important, yielding more than all the tin mines throughout the rest of the world. Malacca and Banca in the East Indies, Saxony, Queensland, and Bohemia are the other chief tin-yielding districts. The deposits of France much resemble those of Cornwall and Saxony, but the ore is not in sufficient abundance to be profitably worked. There are important tin mines at Guanaxuato and Zacatecas, in Mexico. Quartz is the usual gangue for cassiterite, and the minerals that accompany it are—mica, tourmaline, axinite, topaz, apatite, chlorite, molybdenite, tellurium, gold, and platinum.

ZIRCON. (SiO_2ZrO_2 or Silica = 33·67; Zirconia = 66·33. *Syn.* Zyrconite; Hyacinth; Jargon.)

This is usually considered to be a silicate of zirconia, but latterly some mineralogists have been induced to believe it to be a combination of two isomorphous oxides, and we have adopted this opinion. It resembles cassiterite in its chemical constitution and in its crystalline form; its crystals are derived from a right rhombic prism, one common form being the pyramidal variety, shown in Fig. 20, Pl. II., which differs little from a corresponding variety of cassiterite. It has an oily and somewhat adamantine lustre, a hardness of 7·5, a specific heat of ·132, and a specific gravity of 4·68 (52,313), which is rather high for a non-metallic mineral. The colourless varieties from Tyrol and the lake of Laach are seldom found, but those having a red, brown, grey, yellow, or green tint are more frequently met with. Zircon is infusible before the blowpipe, and is usually unaltered; the red varieties are changed to yellow, and the brown are whitened. When mixed with borax it may be fused, but with difficulty.

The *jargon* variety is found in transparent crystals in the granitic rocks of the Pfitsch valley in the Tyrol, and in the trachytic rocks near the lake of Laach; in grey or yellowish crystals in the micaceous rocks, where it is

associated with adularia, rutile, and hæmatite; in bluish crystals associated with nepheline at Mont Somma; in yellow or brown crystals associated with elæolite in *miascite*, a rock nearly allied to syenite. It has also been found in several other localities in France, Ceylon, Norway, Siberia, the United States, and Greenland.

The *hyacinth* variety is usually found in basalts and basaltic rocks, and in the ancient volcanic sands. The principal localities are in volcanic sand, forming the bed of the rivulet of Expailly, near the Puy-en-Velay; and in similar sands at Beaulieu, in Provence, and at Bilin, in Bohemia.

Auerbachite is probably a variety of zircon, in which the proportion of the two oxides is somewhat different from what is found in zircon proper. Its crystalline form closely resembles that of zircon; its hardness is 7·5, and its sp. gr. 4·06 (45,382). *Ostranite* is a variety of zircon, while *malacone* and *oerstedtite* are zircons containing a small proportion of water.

RUTILE. (TiO_2 or Ti = 60·98; O = 39·02. *Syn.* Titanite; Oxide of Titanium; Sagenite; Crispite.)

Its crystals are right rhombic prisms, with four, eight, or twelve sides, terminated by pyramidal summits. They are remarkable for the frequency with which they are met in masses composed of acicular prisms, connected together by their oblique terminal faces, so as to form an angle or knee, as in Fig. 36. The cleavage parallel to the lateral faces of the prism is more distinct than those parallel to the two diagonals of the base.

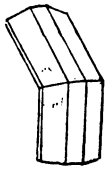

Fig. 36.

Pure specimens are bright red and transparent; the most common colour is cherry-red, and some specimens are brownish. The lustre is metallic or adamantine, the sp. gr. 4·3 (48,055), the sp. ht. ·157, and the hardness 6·5. It is infusible by the blowpipe, and, with borax, gives the reactions of titanic acid. It is insoluble in acids unless when reduced to an impalpable powder, and treated with hot and strong sulphuric acid.

It occurs in minute veins in the more highly crystalline rocks, such as gneiss, mica schist, &c., where it is associated with hyaline quartz, tourmaline, apatite, sphene, hæmatite, chlorite, albite, and several other minerals. The finest crystals have been brought from Rosenau, in Hungary; Buytrago, in Spain; Bona-Vista, in Brazil; and two or three localities in the United States. It has also been found in France, Switzerland, and the Alps.

Xanthitane is a yellowish white, pulverulent, hydrated variety of titanic acid, containing traces of zirconia. It is found in decomposing felspar, Green River, Henderson County, North Carolina. *Nigrine* is a mixture of rutile with titaniferous iron.

ANATASE. (TiO_2 *Syn.* Octahedrite.)

It has precisely the same chemical composition as rutile, but a different crystalline form. The crystals are dimetric octahedrons, in which the terminal edges make an angle of 136° 22′, and the lateral edges an angle of 97° 56′. They possess a distinct octahedral cleavage, and often have their faces longitudinally striated. The usual colour is either indigo-blue or steel-grey, and less frequently honey-yellow, hyacinth-red, clove-brown, and iron-black, when viewed by reflected light, while it is nearly always greenish-yellow by transmitted light. It is therefore a dichroic mineral. The lustre is resplendent and adamantine, the hardness 5·5, the sp. ht. ·161, and the sp. gr. 3·85 (42,935) to 3·95 (44,053). It is infusible by the blowpipe alone, but melts into a yellowish globule when fused with soda. It is soluble in warm concentrated sulphuric acid.

It is far less abundant than rutile, and is most commonly met with in small crystals in fissures in granites and mica schist. In the Alps it forms minute veins along with hyaline quartz, albite, chlorite, and hæmatite. It is found in Cornwall, Devonshire, North Wales, France, Switzerland, Norway, Spain, Siberia, Brazil, and United States. It has been produced artificially by the action of steam on gaseous fluoride of titanium. The temperature at which

anatase formed was a little below that required to volatilise cadmium; while brookite was formed in a similar way at a temperature required to volatilise zinc, and rutile was formed at a red heat. The specific gravity of the anatase thus produced was 3·9, of the brookite 4·2, and of the rutile, 4·3.

BROOKITE. (TiO_2. *Syn.* Jurinite; Arkansite.)

Although it has the same chemical composition as the preceding two species, it possesses a different crystalline form and different properties. Its crystals belong to the monoclinic system, like those of wolframite. The usual form is a rhomboidal or thin hexagonal table, and a less abundant one is a rhombic prism with four-sided pyramidal terminations. In these latter the terminal edges make angles of 101° 3′ and 135° 37′, and the lateral edges an angle of 90° 44′. The colour is yellow, red, brown, or black; the lustre sub-metallic; the specific gravity of the more transparent crystals 4·20 (46,947) to 4·23 (47,381), and of the opaque varieties 3·8 to 4·18; and the hardness 5·5 to 6·0. It is infusible by the blowpipe; but, when calcined, its specific gravity is raised to 4·3 (48,055). It is said to be insoluble in acids. It usually contains small proportions of ferric oxide and alumina.

The crystals occur in a rock composed of quartz and albite containing anatase, at Oisans, in Dauphiné, and associated with rutile in the volcanic tufa at Etna. The other localities are at Tremadoc and on Snowdon, in Wales; on Mont Blanc and St. Gothard; in the Valorsina and the Griserntbal, Switzerland; at Miask, in the Ural Mountains; in North Carolina, and near Magnet Cove, Arkansas. The crystals from this last locality are black, and were formerly thought to be a distinct species under the name of *Arkansite*.

Brookite has been crystallised artificially by the reaction of gaseous chloride of titanium and steam at high temperatures, as well as by the method mentioned under *Anatase*.

Pyrolusite. (MnO_2 or Mn = 63·6; O = 36·4. *Syn.* Polianite; Peroxide of Manganese.)

It crystallises in short, longitudinally-striated prisms, derivable from a trimetric prism with an angle of 93° 40′. It also occurs in mammillated masses, with a granular, fibrous, or earthy structure. Some mineralogists restrict the term *polianite* to the perfect crystals, reserving *pyrolusite* for those which are more or less decomposed or altered. Polianite has a metallic lustre, a clear steel-grey colour, a hardness of 6·5 to 7; a specific heat of ·159, and a sp. gr. of 4·85 (54,213). Pyrolusite has a semi-metallic lustre, an iron-black and sometimes bluish colour, and a hardness of 2·5 to 3. Polianite is convertible into pyrolusite by a change of molecular condition, and the two varieties are frequently associated; pyrolusite also occurs associated with manganite, from which it is believed to be derived.

This mineral is infusible by the blowpipe; but, when heated, loses a portion of its oxygen, giving rise to manganic oxide (braunite), and, at a higher temperature, to manganoso-manganic oxide (hausmannite). The facility with which it gives off a portion of its oxygen has caused it to be much employed as an oxidising agent in chemical operations. It is soluble in sulphuric and hydrochloric acids.

Polianite is more especially met with in the crystalline rocks, while pyrolusite usually occurs in the comparatively unaltered sedimentary ones. The more important mines are at Eglersberg and other places in Thuringia, and at Vorderehrensdorf, in Moravia. It is also found at Romanèche, in the department of the Saône-et-Loire, associated with manganite, psilomelane, barytine, fluorspar, and calcite; at St. Martin, Dordogne, associated with barytine; in the oolitic limestones at Excideuil, Dordogne; in the tertiary sandstone at D'Orsay, near Paris; at several other places in France; in Devonshire; and many parts of the United States.

Varvacite is an impure manganese ore, which appears to contain a large proportion of pyrolusite.

ROCK CRYSTAL. (SiO_2 or Si = 46·7; O = 53·3. *Syn.* Hyaline Quartz; Vitreous Quartz.)

Its crystals belong to the hexagonal system, having for their primary form a rhombohedron with an angle of 94° 15, somewhat like that shown in Fig. 2, p. 29), the prevalent form being the pyramidal prism (Fig. 37)

Fig. 37.

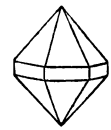

Fig. 38.

Fig. 39.

The cleavages are imperfect and difficult to obtain, but they are generally parallel to the faces of the primitive rhombohedron. The surfaces produced are somewhat curved, and show a tendency to the conchoidal fracture which characterises most varieties of this mineral. The fracture is sometimes rippled, as in the amethyst. The double six-sided pyramids are seldom more than an inch in diameter, but prismatic crystals much larger than this are occasionally found. The faces of the pyramids are generally smooth, while those of the prism are frequently marked with transverse striations. Many of the crystals which are apparently simple are really composed of two or more blended together. These twins are easily recognised by the striations on some of the faces, such as those of the prism, being interrupted; by the different degrees of lustre presented by the same face; and by other signs which cannot be detailed. It would seem, indeed, that these compound crystals are the most prevalent, while the simple ones are exceedingly rare.

Pure rock crystal is colourless, and perfectly transparent; but it is often coloured by foreign substances, which may be combined with it, either as mechanical admixtures or as chemical solutions and compounds. Those

coloured by the first of these methods are more or less opaque, and those coloured by the second are usually transparent. To this latter class belong the more highly prized varieties, such as the *rose quartz* of Bavaria; violet quartz, or the *amethyst;* blue quartz, or *saphirine;* yellow quartz, or *topaz;* and smoky-brown quartz, or *cairngorm stones.* To the former class belong *aventurine,* chloritic quartz, and many others.

The opaque red crystals from St. Jago de Compostella, in Spain, owe their colour and opacity to dispersed flakes of ferric oxide. The ferruginous varieties called *eisenkiesel,* or iron flint, by the Germans, are aggregated masses of minute quartz crystals cemented together by oxide of iron.

The sp. gr. of rock crystal is 2·65 (29,261), its hardness 7, or sufficient to scratch glass, and its sp. ht. ·186. When two pieces of a whitish colour are rubbed together they yield a sort of phosphorescent light visible in the dark, and acquire positive electricity. It is infusible alone by the ordinary blowpipe, but is easily melted by mixing it with a caustic alkali, yielding a glass which is soluble in acids. It has been melted alone, and even volatilised by means of an alcohol flame fed with oxygen. It is insoluble in all acids except hydrofluoric acid. The coloured varieties owe their tints to the presence of minute proportions of alumina, oxide of iron, oxide of manganese, titanic acid, oxide of nickel, and other substances.

Rock crystal, or hyaline quartz, occurs either (1) in crystals and crystalline grains, or (2) as a constituent of crystalline and sedimentary rocks. The crystals are common in granitic and porphyritic rocks, as well as in gneiss, mica schists, and saccharoidal limestones; but rare in serpentines, the trachytic and basaltic rocks, as also in the sedimentary strata. In these last the rolled quartz is the most abundant, and forms the great bulk of sandstones, puddingstones, conglomerates, grits, and sands.

It has been produced artificially by Daubree by the action of steam on gaseous fluoride, or chloride of silicon,

and by M. Senarmont by slowly heating a solution of gelatinous silica in dilute hydrochloric acid to between 200° and 300° F.

No mineral occurs in the crystalline forms of so many other substances as quartz. There are said to be no less than twenty-seven such pseudomorphs. All these pseudomorphous crystals are marked by a dull, porous, and uneven surface. It frequently displaces, and takes the form of calcspar, dolomite, calamine, chalybite, and ligneous fibre. The silicification of shells and wood are examples of the first and last kinds of pseudomorphs.

A massive rose-coloured quartz of considerable translucency occurs at Rabenstein, Bavaria, and is known as the *Bavarian ruby*. Its colour is attributed to the presence of the oxides of titanium and manganese, and its lustre has a peculiar oily appearance. *Sand* and *sandstone* are rolled grains of quartz cemented together by a siliceous, argillaceous, or calcareous paste; sometimes they take the form of the rhombohedrons of calcspar, as at Fontainebleau. *Amethyst* is a violet quartz, having a peculiar structure. It appears to be built up of a number of superposed laminæ composed of different kinds of quartz having different properties, or of the same kind differently arranged. This is the cause of its rippled fracture. By means of polarized light the structure above indicated can generally be made out, especially in some of the crystals from Brazil, or it may be developed by partially dissolving them with dilute hydrofluoric acid. Its colour is attributed to manganous oxide; but since it is destroyed at about 472° F., it is possible it may be due to organic matter. *Cat's-eye* is a brownish-red or greenish-grey, translucent variety, penetrated by amianthus, and presenting a peculiar opalescence when cut in a convex form. Ceylon and the Cape of Good Hope are its principal localities. This opalescence is also found in fire opal. *Aventurine* is a finely granular, translucent variety of grey-green or brown colour, containing a number of brilliant specks. These specks are sometimes composed of mica, and sometimes of copper. *False topaz* is a light

yellow variety found in Brazil. It is much used by the jeweller, who modifies the colour by carefully calcining the stones. *Smoky quartz* is a brownish, or even nearly black, variety found in Brazil and Bohemia. *Prase* is compact, and has a pea-green tint. It is found at Breitenbrunn, in Saxony. A blue variety of quartz from Golling, near Salzburg, is called *siderite.*

There are numerous amorphous varieties of quartz, amongst which the most important are *chalcedony* and *flint.* Flint is a compact variety, generally of a blackish colour, but sometimes yellowish or greyish. It has a slight lustre, a conchoidal fracture, and is somewhat harder and heavier than ordinary quartz. By weathering its external surface is rendered white in the black specimens; and the same effect is produced by a gentle heat. It is remarkably abundant in the uppermost part of the chalk, which is hence known to geologists as the white chalk with flints. It is usually arranged in parallel bands of nodules, from three to seven or eight feet apart, but sometimes as immense continuous sheets, which may be parallel with the bedding of the chalk, or inclined to it at various angles. Layers of a similar kind also occur in the Purbeck and Portland beds. *Hornstone* resembles flint, but differs from it in being more brittle, in breaking with a splintery, uneven fracture, and in not being so hard as quartz. It forms compact layers in limestones of various ages. Its colour is variable, but the most frequent tints are grey, yellowish, or reddish. It closely resembles compact felspar in external appearance, but is readily distinguished from it in being infusible by the blowpipe, whereas felspar is fusible.

Mineralogists apply the term *chalcedonies* to all the amorphous varieties of silica, which break with a scaly fracture, and possess a cloudy transparency, combined with lively colours and a high susceptibility to polish. Those which have a conchoidal or smooth fracture, a dull colour, and do not readily take a polish, are grouped together as *flints.* These terms are also restricted to one variety in each group. *Flint* is the black

variety from the chalk, and *chalcedony* proper is a variety possessing considerable translucency, a bluish-white colour sometimes approaching to lavender, and a peculiar cloudy appearance. It occurs in mammillated, botryoidal, stalactitic, or reniform masses, and sometimes in veins or in layers of variable colour and translucency, lining cavities and fissures in rocks. Specimens having this banded appearance are familiarly known as agates, and are principally obtained from amygdaloidal rocks in the Färoe Islands, and at Oberstein, not far from Coblentz. When the layers are parallel or concentric, and the colours regularly alternate (generally brown and white), it is called *onyx*, and is used for making cameos. This is done by carving out the different parts of the design in one or other of two layers, and in cutting away the part of the uppermost layer not occupied by the design, so as to have a uniform background of white or brown. The apotheosis of Augustus and the Mantuan vase at Brunswick are well known examples of this kind. When some of the bands are red the stone is called a *sardonyx*. *Plasma* is a dull green chalcedony. *Chrysoprase* is an apple-green variety, and probably owes its colour to a little oxide of nickel; it is found at Kosemütz, in Silesia. *Heliotrope* has a green tint spotted with red. The red spots are believed to be jasper, and the green tint to be due to an intimate mixture of ripidolite, a mineral which is green by reflected, and red by transmitted, light. Hence, when the stone is placed in water its translucency is increased, and the sun's image being seen in it by transmitted light, might appear to be red, as stated by the ancients. Its name is said to have been given it in consequence of this power to make the sun appear red. *Carnelian* is a red chalcedony; its natural colour is a pale or light red; but the tint is darkened by exposing the stones to the sun's rays for several months. The finest specimens are brought from Arabia; from Surat and Cambay, in India; from New Zealand, and Saxony. There are many other localities. *Moss* agates derive their name from the moss-like red and green dendritic forms which they contain. These forms are gene-

rally composed of oxides of iron and manganese; but it is stated that in some cases they are really of vegetable origin. *Lydian* stone, or *touchstone*, is an impure carbonaceous flint of a dark or blackish-green tint. It is used by jewellers for testing the quality of a gold alloy; the colour of the streak varying with the proportion of gold, an experienced eye is enabled to judge approximately how much gold is present. *Beekite* is an impure variety of chalcedony.

Opal. (*Syn.* Hydrate of Silica.)

This never occurs in a crystalline form. It is composed of a combination of silica and water, the proportion of the latter varying from 3 to 13. Its hardness (5·5 to 6·5) is less than that of rock crystal, as also is its specific gravity, which varies from 1·9 (21,238) to 2·3 (25,899). The specific heat is somewhat higher than that of quartz, and is probably about ·200. Its fracture is conchoidal; its lustre vitreous, sometimes inclining to resinous; and its colour variable, as indicated in the descriptions of the varieties. It is distinguishable from quartz by its lower specific gravity, its non-crystalline form, its complete solubility in a solution of potash, and in decrepitating when heated. These differences appear to be due, not to the water, but to the silica of opal being different from the silica of quartz. According to Frémy, they are two allotropic forms of the same substance, one of which is denser than the other. The one is represented by quartz, with a sp. gr. of 2·6, and which is insoluble in dilute alkaline solutions; the other by the silica obtained when opal is calcined, or when the hydrated silicates are decomposed: this has a sp. gr. of 2·2, and is soluble in alkaline solutions. Their chemical behaviour, moreover, is as distinct as their physical properties, and is thus pointed out by Frémy, who calls the silica of quartz silicic acid, and that of opal metasilicic acid. Metasilicic acid forms salts quite distinct from those produced from quartz. The alkaline metasilicates are soluble in water, gummy, and uncrystallisable, and if required in a solid state should

be precipitated from their solutions by means of alcohol. Water is an important constituent in many of the metasilicates, so that when liberated by means of heat the acid is separated from its base. When an alkaline metasilicate is treated with an acid, a hydrate is formed from which the anhydrous silicic acid can be obtained by decomposing it at a red heat. This acid resembles quartz, but retains its solubility in dilute alkaline solutions. By exposing it to a high temperature for a long time it may be converted into the insoluble variety. Both the alkaline silicates and metasilicates contain water of crystallisation; but in the former group this water does not act the part of a base, so that when such silicates are exposed to a red heat the water is driven off without causing the decomposition of the salt, and the consequent separation of the silica. The silicates are generally denser than the metasilicates, more difficult to decompose, and when decomposed they yield the insoluble modification of quartz.

There are many varieties of opal. *Hyalite* (Muller's glass) is transparent, and colourless. It occurs in small botryoidal masses, like nodules of glass, on the surface of lavas and trachytes in Auvergne, near Frankfort-on-the-Maine, and at Schemnitz; also in quartzite and serpentine in Silesia; on basalt in Bohemia; and at some other localities in Mexico, Africa, and the United States. It contains very little water, and when this is driven off, acquires a beautiful pearly lustre. It has no action on polarised light, behaving in this respect like a gummy or colloidal substance. Its index of refraction is 1·435; while that for the ordinary ray in quartz is 1·54. *Fire opal* is translucent, and has a yellowish, or reddish, and somewhat iridescent tint. *Noble opal* is the variety usually called opal by lapidaries, and is the kind commonly employed by them. It is semi-transparent, and of a milky or yellowish-white colour; its beauty is chiefly derived from the iridescent reflections, which are seen when the stone is moved about in the light. It is found in a trachytic rock at Czerwenitza, near Kaschan, in Hungary; at Guatemala, in Mexico; and in the amygdaloidal rocks of

the Färoe Islands and Iceland. The specimens are seldom larger than a hazel nut; but there is one specimen in the imperial collection at Vienna nearly as large as a man's fist. Opals are also obtained from some of the mines in Honduras; and beautiful blue ones are found in Queensland. *Common opal* is translucent and vitreous; its colours are various, but it does not possess the brilliant reflections of the noble opal. It abounds in Hungary, Iceland, and the Hebrides; at the Giant's Causeway, and near Smyrna. It forms nodules and layers in many argillaceous rocks. *Semi-opal* and *menilite* somewhat resemble the last mentioned variety, but the colour is generally darker. *Cacholong* is slightly translucent, and bluish-white. *Hydrophane* is yellowish, porous, and opaque; but when it is placed in water the air-bubbles are displaced, its opacity is changed to translucency, and its index of refraction is increased. The *tabasheer*, constituting the siliceous concretions formed in the bamboo, closely resembles hydrophane in its properties, such as becoming translucent and acquiring a higher index of refraction when plunged in water. *Nectic quartz* is a highly porous opal. *Geyserite*, or *siliceous sinter*, is an opaline silica deposited from hot springs. That deposited by the Geysers of Iceland has a light grey colour, with occasionally a pearly lustre. The surface is generally covered with a white powder, composed of minute spherical globules, and the mass of the stone itself appears to be made up of a multitude of these spheres embedded in a gelatinous paste. *Michaelite*, *glossecollite*, *randanite*, and *fiorite*, are other varieties.

ARSENOLITE. ($As_2 O_3$ or As = 75·81; O = 24·19. *Syn.* Arsenite; Arsenious Acid; Arsenic Bloom; White Arsenic.)

It usually occurs in granular, semi-crystalline masses and coatings, in which may be developed a few acicular crystals, which are evidently prisms; while octahedral crystals are still more rarely formed. The artificial arsenious oxide is known in three different states, viz., the

amorphous, or *vitreous*, the *octahedral*, and the *right rhombic* varieties. These varieties have different specific gravities, that of vitreous arsenious oxide being 3·73 (41,592), and that of the crystallised oxide 3·69 (41,146). The vitreous variety generally passes into the octahedral kind if kept for a time in contact with the air; this last, indeed, is the most stable and the most dominant form. Arsenolite resembles white antimony in crystallising in octahedrons and rhombic prisms. The native arsenious oxide usually has a sp. gr. of 3·69 to 3·71. The colour of the pure oxide is white, and of a greyish white, or even yellow, red, and green in the impure specimens. The lustre is vitreous, the fracture conchoidal, and the hardness 1·5 in the amorphous masses, but about 3 in the crystals. It is slightly soluble in water; but the vitreous is more soluble than the crystalline variety.

This mineral is rare in the native state, and has been found in some mines containing arsenical ores, in which it is nearly always met with on the surface of other minerals; a fact which has led some to infer that its formation has been effected by means of artificial heat. It has been detected in solfataras and the craters of some old volcanoes. The best known localities are at Andreasberg, in the Harz; Joachimsthal, in Bohemia; Bieber, in Hanau; Kapnik and Malaczka, in Transylvania; St. Marie-aux-Mines, in Alsace; and in the valley of Gistan, in the Pyrenees. It is used for many purposes in the arts.

SENARMONTITE. ($Sb_2 O_3$ or Sb = 84·3; O = 15·7.)

This is the octahedral form of antimonious oxide found in considerable quantity in a mine near Sanza, in the Constantine province, Algeria; and also at Perneck, Hungary. It occurs in granular masses, in the cavities of which a few small octahedral crystals are occasionally found. The crystals are colourless or greyish white, and have an adamantine lustre, a hardness of 2 to 2·5; and a sp. gr. of 5·23 (58,459). In its other properties it scarcely differs from Valentinite.

VALENTINITE. ($Sb_2 O_3$. *Syn.* White Antimony; Antimony-Bloom.)

This is the antimonious oxide in another crystalline form. The crystals are derived from a right rhombic prism with an angle of 136° 58′. They are acicular prisms of a shining white or yellowish colour, with a pearly lustre on the lateral faces, and an adamantine one on the terminal faces. The hardness is 2·5 to 3; and the sp. gr. 5·6 (62,596). The two forms of antimonious oxide are isomorphous with the two forms of arsenious oxide. It fuses below a red heat; and at a somewhat higher temperature than its fusing point volatilises in white fumes, which are partly composed of antimonic oxide. It is sparingly soluble in water, but freely soluble in hydrochloric acid; the latter yields a clear solution, which is rendered turbid by the addition of water.

It occurs in the primary rocks; the principal localities are at Wolfsberg, in the Harz; at Braunsdorf, in Saxony; and at Przibram, in Bohemia; as also in Hungary, Algeria, and France.

BISMUTH OCHRE. ($Bi_2 O_3$ or $Bi_2 = 89·9$; $O = 10·1$.)

This is known to the chemist as bismuthous oxide, and forms a yellowish or greenish pulverulent coating, which appears to be derived from the decomposition of the sulphide of bismuth (bismuthite). It is readily fusible into a brownish fluid, which on cooling turns yellow. It is soluble in nitric acid, and water precipitates it from the solution. It is found at Schneeberg, in Saxony; at Joachimsthal, in Bohemia; at Beresof, in the Ural Mountains, associated with gold; and at St. Agnes, in Cornwall.

WOLFRAMITE. (*Syn.* Tungstic Ochre.)

A mineral consisting almost wholly of tungstic acid ($W_2 O_3$), sometimes forming the nucleus of rhombic crystals of tungstate of iron and manganese (Wolfram). It is reported to have been found in North Carolina and Missouri.

SASSOLIN. ($B_2 O_3$. 3 H_2 O or Boric-oxide = 56·38; water = 43·62. *Syn.* Boracic Acid; Oxide of Boron.)

This is the well-known boracic acid of the lagoons of Tuscany, occurring as white or yellowish fibrous or flaky incrustations; or as a solution in water. The crystals obtained from the aqueous solution are six-sided laminæ, derivable from an oblique prism, with angles of 118° 30′ and 84° 53′, and a distinct cleavage parallel to the base. The sp. gr. is 1·48 (16,543); and the hardness 1 to 1·5. It has a faintly acid and slightly bitter taste; dissolves in 2·5 parts of water at about 64°; but is more readily soluble in alcohol, yielding a solution which burns with a beautiful green-edged flame.

The great bulk of the boracic acid of commerce is obtained from the vapours which escape through holes in the ground, called *suffioni*, by enclosing the apertures with a basin of masonry, filling the basin with water, and evaporating the aqueous solution until the boracic acid is crystallised out. The vapours contain only a small proportion of the boracic acid, and consist mainly of aqueous vapour, carbonic acid, and sulphuretted hydrogen. The richest suffioni are those at Cherchiago, Monte Cerboli, and Castel Nuovo. The suffioni are generally situated in valleys, but some occur on the slopes or summits of hills. Those at Monte Cerboli form a long line about 700 feet in length at the bottom of a deep straight valley. Sassolin has also been found in the crater of Vulcano, where it forms a crust remarkably free from impurities; and in several mineral waters, such as those at Wiesbaden, Krankenheil, Olette, Aachen, and Bex.

Various explanations have been proposed to account for its occurrence in the suffioni vapours; but none appear to be satisfactory.

ANTIMONY-OCHRE. ($Sb_2 O_4$. *Syn.* Cervantite.)

This appears to be a compound of antimonious ($Sb_2 O_3$) and antimonic ($Sb_2 O_5$) oxides, into which it is easily resolved by numerous chemical reagents. It occurs in

acicular crystals, or forms a compact or pulverulent crust on other substances. Its colour is yellowish; its lustre greasy or earthy; and its sp. gr. 4·08. It is soluble in water, but more so in hydrochloric acid. It is found at Pereta, in Tuscany; Cervantes, in Galicia, Spain; France; Hungary; at several localities in Cornwall; at Hare Hill, in Scotland; in large crystals in Borneo; in Mexico, Canada, and California.

Manganosite. (Mn O.)

The protoxide of manganese occurs in minute isometric crystals, usually the octahedral and dodecahedral modifications, rarely the cubic. Hardness 5—6; sp. gr. 5·18; lustre vitreous; colour emerald green on fresh surface, but black on those which have been exposed to the air. It dissolves with difficulty in strong nitric acid, forming a colourless solution. It is found in dolomite or calcite associated with various manganese ores at Långban, Wermland; also at the Morsgrufva, in Nordmark, Sweden.

Chrompicotite.

It is a chrome-iron-magnesium oxide which seems to be a variety of chromite from which it chiefly differs by its great hardness (8) combined with its low sp. gr. (4·1). It is found at Dun Mt., New Zealand.

Jacobsite.

It is apparently a combination of the peroxide of manganese and iron with magnesia and protoxide of manganese having a constitution analogous to that of Franklinite. The crystals are octahedral. It scratches glass, and has a sp. gr. of 4·75. The lustre is brilliantly metallic, and the colour deep black. It is found at Jacobsberg, in Sweden, associated with white mica and native copper in crystalline limestone.

Hydrocuprite.

A hydrated cuprite, which occurs in thin amorphous coatings of an orange yellow to orange red colour on

magnetite. Occasionally fine red crystals of cuprite gradually change to an orange yellow colour indicating their change by pseudo-morphism into hydrocuprite. It is found at Cornwall, Lebanon co., Pennsylvania.

Tridymite. ($Si O_2$.)

Several new forms of silica have been lately recorded. One of these is called tridymite by Von Rath; the name referring to the groups of three crystals in which it usually occurs. It crystallises in small colourless and transparent hexagonal tables, which are said to have the double refraction of an optically uniaxial substance. The hexagons are pseudosymmetrically arranged twin crystals belonging to the triclinic system. The sp. gr. is 2·2, or approximately that of opal. It has been met with at Mount Tardree, near Antrim; near Padua; in druses in a volcanic porphyry from Cerro S. Cristoval, near Pachuca, in Mexico; in the orthoclace porphyry of Waldbockelheim; in the trachyte of Drachenfels; and in the white ashes ejected from the island Vulcano.

Asmannite. ($Si O_2$.)

This is a second crystalline form of silica with a sp. gr. of 2·2. The crystals belong to the trimetric system. The lustre is generally resinous resembling opal, and the hardness 5·5, while it is remarkably brittle. It is optically biaxial, the two axes being highly divergent. It is doubly refractive. It is found in small grains in the Breitenbach meteoric iron.

Cottesite.

A form of quartz which occurs as pearly splendent films on the face of ordinary quartz, which have the same hardness as quartz, and which seem to be formed of interlaminated fibres of pure silica and of limonite. Found at Rock Forest, co. Cork.

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BAUXITE is not a true mineral species, being a concretionary mixture of hydrate of alumina with hydrated peroxide of iron. It is an important aluminium ore.

CHAPTER VII.

CARBONATES.

ARRAGONITE. (CO_2 CaO or CO_3 Ca or CO_2=44; CaO=56. *Syn.* Hard Carbonate of Lime; Rhombic Carbonate of Lime.)

Carbonate of lime constitutes two species of minerals, arragonite and calcite, which differ in crystalline form, in molecular structure, and to a greater or less degree in their physical and chemical properties, although both have precisely the same chemical composition. It is needless to point out here what the distinctions are, as they will be readily seen on comparing the descriptions of the two minerals.

The crystals seldom occur isolated, but combined together into groups, which frequently appear to consist of a single isolated crystal. They are trimetric and derivable from a right rhombic prism, with angles of 116° 10′ and 63° 50′. The compound masses present a great variety of symmetrical forms, but they also occur in aggregates whose structure may be bacillar, acicular, fibrous, coralloidal (*flos ferri*) or compact.

The colour of pure arragonite is white, but it may be coloured various shades of green, blue, yellow, violet, and red, mechanically and chemically, by certain substances; the fracture is conchoidal or uneven; the lustre vitreous; the hardness 3·5 to 4; the sp. heat ·203; and the sp. gr. 2·93 (32,750). It has the power of doubly refracting light. When subjected to a low red heat, arragonite decrepitates, becomes phosphorescent, and falls into a powder, which, on examination, is found to be composed of minute crystals of

calcite. It is soluble in hydrochloric and other acids, but far less readily than calcite, and it is also soluble in water. The substances which usually occur as impurities are carbonates, especially the carbonates of strontia, lead, &c., or those whose crystals are isomorphous with the crystals of arragonite. The variety containing nearly 4 per cent of carbonate of lead is called *Tarnowitzite.*

Arragonite never constitutes rock masses, but forms clusters of crystals in mineral veins, especially such as contain iron; in beds containing altered gypsum; and in numerous rocks which are mainly composed of lime-compounds, such as serpentine, fresh-water lime-stones, &c. It is also found in basaltic rocks. The localities from which it has been obtained are exceedingly numerous, but many of the finest groups of crystals have been brought from Cziczow, near Bilin, in Bohemia. Very fine ones occur in a red clay near Molina, in Arragon, and in Valencia; and beautiful specimens of the variety called *flos ferri*, having a striking resemblance to snow-white coral, have been brought from some of the mines in Styria, Bohemia, and Westmoreland. It is difficult to say what are the conditions which induce carbonate of lime to crystallise as arragonite. The general opinion seems to be that it is formed when the crystallising process is rapid, as when hot calcareous solutions are cooled and concentrated by evaporation. This view is supported by several facts—thus, hot springs usually produce arragonite, and cold ones calcite; again, when gypsum is immersed in a concentrated solution of carbonate of soda, arragonite is formed; but when the solution is diluted calcite is formed. But there are also facts which seem to support the opposite view. Thus, when the solution of carbonate of lime is weak and flows in an intermittent manner into cavities (from which air is excluded) having a uniform and low temperature, so as to cause the evaporation to be slow, then arragonite is formed, especially the variety called *flos ferri.* This would seem to be the conditions under which the beautiful crystalline aggregates in caverns filled with carbonic acid at Dufton Fell mine were formed. In

cases where the cavity is exposed to the air ordinary limestone is formed.

MANGANOCALCITE. ($2\,CO_2\,MnO.\,CO_2\,CaO.$)

It crystallises in prisms and needles closely resembling those of arragonite, and possesses the same cleavages as that mineral. It has a vitreous lustre, and a transparent flesh-red colour. It is of rare occurrence, the only known locality being at Schemnitz, Hungary.

ALSTONITE. ($CO_2\,CaO.\,CO_2\,BaO.$ *Syn.* Bromlite.)

It occurs in crystals derivable from a right rhombic prism of 118° 50′, which are frequently aggregated in groups of three, which form what appear to be single bipyramidal crystals. Many of the faces are triangular, and marked by a central groove and transverse striæ, which meet on opposite sides of the groove at similar angles. It has been found at Bromley Hill lead mine, near Alston Moors, Cumberland, and at Fallowfield, in Northumberland.

WITHERITE. ($CO_2\,BaO$, or $CO_2 = 22{\cdot}33$; $BaO = 77{\cdot}67$. *Syn.* Barolite; Carbonate of Barytes.)

It occurs in compact, fibrous, and acicular masses, as also in small aggregations of crystals. These last belong to the trimetric system, and are derivable from a right rhombic prism with an angle of 118° 30′, so that they are isomorphous with those of arragonite. The usual forms are hexagonal prisms and double hexagonal pyramids. Pure specimens are transparent and colourless, but the impure crystals are translucent and yellowish or greyish. The lustre is vitreous, except on the fractured surfaces, which present a vitreous lustre. The fracture is uneven, the hardness 3 to 3·75, and the sp. gr. 4·29 (47,953) to 4·35 (48,614). When heated in the blowpipe flame it decrepitates, colours the flame greenish, and melts into a transparent globule, which becomes opaque on cooling. It is very slightly soluble in pure water, but more soluble in

carbonated water. It is also soluble in most acids with evolution of carbonic acid.

It is commonly found in lead veins associated with the various minerals characteristic of such veins; the principal localities are Anglesark, in Lancashire; Snailback, in Shropshire; Alston Moor, in Cumberland; Fallowfield, in Northumberland; near Neuberg, in Styria; at Leogang, in Salzbourg; and at Tarnowitz, in Silesia. It is also found in the Altai Mountains and in South America.

STRONTIANITE. (CO_2 SrO or $CO_2 = 36{\cdot}4$; SrO = 63·6.)

Its crystals are isomorphous with those of arragonite and witherite, and they form symmetrical groups which strikingly resemble the groups formed by the minerals named. Strontianite, like them, is also found in acicular and fibrous masses. The primary crystalline form is a right rhombic prism with an angle of 117° 19′. The commonest form is an irregular hexagonal prism. There are cleavages in two directions, the more perfect being parallel to the vertical faces of the prism. The crystals are generally colourless, but they sometimes present various shades of green, grey, yellow, and brown. The lustre is vitreous on the natural faces, but resinous on the surfaces produced by fracture. The hardness is 3·5 to 4; and the sp. gr. 3·6 (40,140) to 3·71 (41,370). When heated by the blowpipe the edges melt and the flame is tinged red. It is very sparingly soluble in pure water, also in water containing carbonic acid, and readily soluble in hydrochloric acid.

It has only been found in veins containing metalliferous ores. Thus, at Strontian, in Argyleshire, it occurs as asparagus-green needles in a vein of galena, barytine, and calcareous spar traversing gneiss. Among its other localities are Leogang, in Salzburg; Braunsdorf, in Saxony; and Clausthal, in the Harz. *Baryto-strontianite*, or *stromnite*, as it is frequently called, is a variety from Stromness, in the Orkneys, largely mixed with carbonate of baryta. *Emmonsite* is also a variety of strontianite.

CERUSITE. ($PbO.CO_2$ or $PbO = 83{\cdot}5$; $CO_2 = 16{\cdot}5$. *Syn.* White Lead Ore; Carbonate of Lead; Lead Spar.)

It is either granularly compact, fibrous, earthy, or crystalline. Its crystals are trimetric, and derived from a right rhombic prism with an angle of 117° 14′; and are therefore nearly isomorphous with those of strontianite, witherite, and other carbonates. There are further resemblances in the way in which the crystals are modified and grouped together, as, for example, the six-rayed stars and almost regular hexagonal prisms formed by the aggregation of many crystals. Figs. 40 and 41 represent some

Fig. 40.

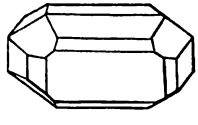

Fig. 41.

of the crystals. It is colourless when pure, possesses a strong adamantine lustre, and breaks with a conchoidal fracture. The sp. gr. varies from 6·46 (72,209) to 6·48 (72,433), and the hardness from 3 to 3·5, or even less than 3 in the earthy varieties. The sp. heat is ·079.

Cerusite is readily blackened when exposed to a stream of sulphuretted hydrogen, and many natural specimens have this blackened appearance, which in most, perhaps all, cases is due to their intermixture with sulphide of lead or silver, and not to the action of the gas. When heated by the blowpipe the carbonic acid is driven off, and by means of the reducing flame a globule of lead may be separated. It dissolves in nitric acid, and the solution precipitates brilliant laminæ of metallic lead upon a bar of zinc, when immersed in it. The action of water containing phosphate of lime converts cerusite into phosphate of lead; sulphuretted hydrogen converts it into galena; oxidation into minium; and it is also frequently more or less altered into magnesite, malachite, and chrysocolla. It

is nearly always associated with galena, and consequently the remarks made on the distribution of galena will for the most part apply to cerusite. The finest crystals are brought from Poullaouen and Huelgoat, in France; Huel-Penrose, in Cornwall; and Leadhills, in Scotland

CALCSPAR. ($CaO.CO_2$. *Syn.* Calcareous Spar; Calcite; Carbonate of Lime.)

Chemically this is identical with arragonite, but structurally it is different from it. The crystals are derived

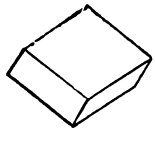

Fig. 42.

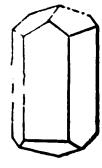

Fig. 43.

Fig. 44.

from an obtuse rhombohedron, Fig. 42, whose terminal edges make an angle of 105° 5′.

No species of mineral presents a greater variety of form than calcspar, yet, whatever be the shape, this primary rhombohedron may be readily obtained by cleavage; the cleavages are perfect, and a slight shock suffices to develop them. The varieties of form which have been described and figured by Haüy, Bournon, Levy, Zippe, and others, amount to several hundreds in number; but the most common are those represented in Figs. 42—44, and in Fig. 20, Pl. II. The last is the form of the variety known as *dog's-tooth spar*, which is so abundant in Derbyshire and elsewhere.

Calcspar is generally transparent and translucent, and when pure is colourless; but it may be tinged various shades of grey, blue, green, yellow, red, brown, and black, owing to the presence of mechanical or chemical impurities. The lustre is usually vitreous, but the faces corresponding to the hexagonal prism are frequently pearly. Its hardness is 3, and the sp. gr. of the purest crystals is 2·721 (30,415). The sp. heat is ·2085, and it possesses

the property of doubly refracting light in a high degree, especially in the variety called *Iceland spar*. It is rendered positively electrical by friction or compression. When acted on by the blowpipe, or when calcined, the carbonic acid is driven off, and the white caustic lime remains. This decomposition goes on at a much lower temperature when a current of air or steam is passed over the calcspar. It is readily soluble with effervescence in hydrochloric acid, and is sparingly soluble in pure water, though somewhat more readily in water containing carbonic acid. It is pseudomorphous after gaylussite, anhydrite, gypsum, heavyspar, and fluorspar; but there are many more minerals which are pseudomorphous after it, and all of these (nearly thirty) are less soluble in water than calcspar. Amongst them may be mentioned bitter spar, manganese spar, zinc spar, malachite, quartz, opal, göthite, brown hæmatite, iron pyrites, arragonite, white iron pyrites, pyrolusite, hausmannite, manganite, galena, chlorite, and others.

Calcspar is one of the most abundant and widely-distributed of the minerals, and is perhaps only inferior in this respect to quartz. Most of the shells of the mollusca are largely composed of it, both in the living and the fossil state. It occurs in almost all geological formations; thus it constitutes most of the granular metamorphic limestones; and it abounds in the shelly limestones and marls. The crystals are usually found in metalliferous veins, associated with blende and galena.

The best known varieties which do not form distinct crystals are the following:—

Satinspar is a fibrous variety, which acquires a satiny lustre when polished. It is found at Dufton, in Cumberland, in veins traversing shale, and in several other localities in Great Britain. The fibrous variety of *gypsum* (sulphate of lime) is also called satinspar. *Limestone* is the name for the massive varieties of carbonate of lime, the description of which belongs to lithology. *Iceland spar* is a limpid transparent calcspar, found at Rödefiord, on the east coast of Iceland.

It occurs in large nodules in an amygdaloidal trap, and is usually associated with stilbite. Sometimes it is scarcely more than translucent, but the purer specimens are beautifully transparent. The latter kinds are much in request for enabling the physicist to study the phenomena of the double refraction and polarisation of light. *Slatespar* is a massive variety, occurring in thin, friable, laminæ. It is found at Bergmannsgrün, near Schwarzenberg, in Saxony; at Botallack and Delabole, in Cornwall; at Strontian, in Argyleshire, and at many other localities. *Rock milk*, or *agaric mineral*, is finely comminuted slatespar. *Stalactites* are the transparent, semi-crystalline pendents formed by the partial evaporation of slowly dropping water holding carbonate of lime in solution. The layer formed on the floor below is termed *stalagmite*. Both these varieties are frequently composed of layers or bands, having different degrees of lucidity or colour, and are often worked into vases, slabs, &c. When such water forms rivulets, and these flow out into the open air as springs, a portion of the carbonic acid is immediately given off, causing some of the carbonate of lime to be deposited. These deposits are called *calcareous tufa*. The so-called petrifying springs of Derbyshire are examples of this; but in other countries they are sometimes developed on a much larger scale. Thus in Auvergne the calcareous matter deposited by one river has formed a broad and solid arch of stone strong enough to support carriages; while a second has formed an embankment 240 ft. long and 16 ft. high. *Plumbocalcite* is a variety occurring in rhombohedral crystals, and containing a small proportion of the isomorphous carbonate of lead. The formula assigned to it is $PbO.CO_2 + 32\,CaO.CO_2$.

MAGNESITE. ($MgO.CO_2$ or $MgO=48{\cdot}3$; $CO_2=51{\cdot}7$. *Syn.* Giobertite.)

This mineral consists of carbonate of magnesia, and crystallises in rhombohedral crystals, isomorphous with those of calcspar, in which the terminal angle equals 107° 25′, and the cleavages are distinct parallel to the faces

of the rhombohedron. It occurs in many other rhombohedral forms, the counterparts of which are met with in calcspar. It is also found in granular, fibrous, or radiated masses. The pure crystals are colourless and transparent, but impure varieties present various shades of yellow, grey, and brown. The lustre is vitreous, the fracture conchoidal, the hardness 4·5, and the sp. gr. 2·8 (31,298) to 3· (33,434). It is infusible by the blowpipe, and soluble in acids, but the solution is accompanied by a slight effervescence only. *Breunerite* and *giobertite* are varieties of magnesite.

Magnesite is found in the magnesian rocks, such as serpentine, talcose schist, chlorite schist, and in metalliferous veins. It is commonly associated with opal, a fact which seems to indicate the probability of its formation by the action of carbonic acid on silicate of magnesia. A thick bed of it occurs at Bolton, Canada, interstratified between steatite and an impure serpentine. It is composed of brilliant grains of magnesite intermingled with grains of white hyaline quartz. Magnesite frequently contains large proportions of silica, water, and carbonates of lime, manganese, and iron. It is found at numerous localities in Moravia, Norway, Silesia, Piedmont, Spain, and the United States.

DOLOMITE. ($\overbrace{Ca : Mg}.O.CO_2$. *Syn.* Miemite; Bitterspar; Brownspar; Pearlspar; Talcspar; Magnesian Limestone.)

This is a combination of magnesite and calcite, usually in equal proportions, but the proportion may vary considerably. Thus some dolomites contain two parts of calcspar to one of magnesite, such as *gurhofian* or *gurhoffite*, the white, compact, porcelain-like dolomite of Styria; others have two parts of magnesite to one of calcspar, such as *konite*.

Dolomite crystallises in rhombohedrons very similar to those of calcspar, but with a terminal angle of 106 15, which is intermediate between the angles of the crystals of magnesite and calcspar. The modified crystals are

also similar to those of calcspar, and like them are generally colourless, but in some cases are tinged with red, grey, yellow, or green. The lustre is usually pearly; the hardness is 3·5, the sp. heat is ·206, and the sp. gr. 2·8 (31,298) to 3 (33,434). It is distinguished by the angle of the rhombohedron obtained by cleavage, by its somewhat greater hardness, by the greater predominance of the pearly lustre, and by its dissolving slowly in cold nitric acid with scarcely any effervescence. In the crystallised varieties the ingredients seem to be present in atomic proportions, but in the amorphous varieties the proportions seem to indicate that they are in a state of mechanical mixture. It occurs in the magnesian rocks, such as steatite, chlorite, and serpentine.

The following are the principal varieties of dolomite:—

Pearlspar or *Brownspar*, embracing the specimens with curved shiny faces and a pearly lustre. They are generally colourless, but are sometimes reddish, brownish, yellowish, or greenish. They are found in lead mines in various parts of Europe.

Brossite is a crystallised variety containing a large proportion of carbonate of iron. *Ankerite* is a variety in which the magnesium has been partly replaced by iron and manganese.

Magnesian Limestone is finely granular, and frequently of a yellowish-grey colour. It forms beds, sometimes of great extent and thickness, belonging to every geological age, from the Laurentian system up to some of the coral reefs of very recent formation.

Mesitine Spar. ($\overline{Mg : Fe}\,O.CO_2$ *Syn.* Pistomesite.)

This species is composed of spathic iron ore, or chalybite and magnesite, frequently in equal proportions. The crystals are rhombohedrons, with a terminal angle of 107° 14′, having a grey or yellowish-brown colour, a vitreous and slightly pearly lustre; a hardness of 4 to 4·5; a specific gravity of 3 (33,434) to 3·6 (40,140), and a transparency somewhat greater than that of chalybite It is found in chlorite slate at St. Gothard, also in the Zillerthal, in the Tyrol, and in Piedmont.

CHALYBITE. ($FeO.CO_2$ or $FeO=62{\cdot}66$; $CO_2=37{\cdot}94$. *Syn.* Spathic Iron Ore; Siderite; Siderose; Brownspar; Sphaerosiderite; Junkerite; Ironspar.)

This is an abundant mineral, the crystals of which are derivable from a rhombohedron with a terminal angle of 107°, and the modified forms of which resemble the corresponding forms of calcspar. Beautiful groups, having the form of a flat rhomboid with curved edges, occur at Piedmont, and at Baigorry in the Pyrenees; hexagonal prisms are found at St. Agnes, Cornwall, and other varieties in Cumberland. The colour is variable, and may be ash-grey, yellowish grey, greenish grey, or reddish and brownish black. These last two colours are due to the formation of hydrated peroxide of iron. The lustre is vitreous, the fracture uneven, the hardness 4, and the sp. gravity 3·4 (38,005)—3·7 (41,248). The last two characters serve to distinguish it from calcspar. When heated by the blowpipe it gives rise to a brown powder, which ultimately melts, and yields a black magnetic globule. It is soluble in acids, but slowly and with little effervescence; the solution formed gives a precipitate when ferrocyanide of potassium is added to it. The mineral is rarely pure, but contains more or less of the carbonates of manganese, magnesia, and lime; thus in some varieties, such as *oligonspar*, there is 25 per cent. of the protoxide of manganese, and in others there is from 12 to 15 per cent. of magnesia.

It occurs generally in a spathic and crystalline state as threads, lumps, and wavy veins in metamorphic rocks. At Ruszkberg it forms a bed interstratified with metamorphic schists, which is altered in places into magnetite and specular iron. It is found in gneiss, mica slate, clay slate, and abundantly in the argillaceous sandstones of the coal formation. When largely mixed with clay, sand, and various carbonates, it forms the *clay iron ore*, which occurs in brown earthy flattened nodules in many of the French and British coal-fields. *Sideroplesite* is a variety containing carbonate of magnesia, and represented by the formula $3\,FeO.CO_2 + MgO.CO_2$.

DIALLOGITE. ($MnO.CO_2$, or $MnO=61{\cdot}73$; $CO_2=36{\cdot}27$. *Syn.* Carbonate of Manganese; Red Manganese; Rhodocrosite; Brownspar; Manganese Spar.)

It is isomorphous with calcspar, and crystallises in rhombohedrons, having a terminal angle of 106° 51′, as also in flat tables and hexagonal prisms. The colour is rose-red or brownish; the lustre vitreous, inclining to pearly; the fracture uneven; the hardness 4 to 5, and the sp. gr. 3·4 (38,005) to 3·6 (40,140). It is infusible by the blowpipe alone, but when treated with a flux it gives the reactions of manganese. It dissolves slowly in cold hydrochloric acid with effervescence. When heated to redness in the air, or when slowly oxidised at ordinary temperatures, it gives rise to the brownish-black hausmannite. Examples of this change are met with in many altered rocks, such as the grey dolomite of Sutton, Canada; the olive-coloured slates of Silurian age in Pennsylvania and Newfoundland. This change is also the cause of the brown colour of many specimens of diallogite. Diallogite usually contains variable proportions of carbonates of lime and of magnesia, as also of *rhodonite*, the bisilicate of manganese. It is a rare mineral, and has been found at a few localities in Saxony and the Harz; also at Nagyag, in Transylvania, where it is associated with telluride and sulphide of manganese; at Kapnik, in Hungary, where it is associated with sulphide of antimony and blende; at Vielle, in the Pyrenees; at Glendree, Clare co., Ireland, where it forms a pulverulent layer two inches thick; and at Washington, Connecticut, where it is also in the pulverulent form.

CALAMINE. ($ZnO.CO_2$ or $ZnO=64{\cdot}5$; $CO_2=35{\cdot}5$. *Syn.* Carbonate of Zinc; Zincspar; Smithsonite.)

It is generally found in botryoidal and stalactitic masses, but sometimes in crystals. These may be either rhombohedrons with a terminal angle of 107° 40′, rhombohedrons derivable therefrom, or hexagonal prisms. When pure its colour is white, but from the presence of other

carbonates, chiefly those of iron and manganese, it may have a grey, brown, or greenish tinge. The lustre is vitreous, inclining to pearly, the fracture imperfectly conchoidal, the hardness 5, and the sp. gr. 4·45 (50,301). It is soluble in nitric acid with effervescence, and when heated in the reducing flame of the blowpipe it volatilises, at the same time yielding an intensely brilliant light characteristic of zinc.

Pure calamine is rare, but has been found in Derbyshire and Somersetshire; the impure varieties constitute the principal zinc ore. One variety contains more or less of the silicate of zinc (Smithsonite); another, having a greenish colour, contains carbonate of copper; another, having a brownish or yellowish hue, contains carbonate of iron; and there are others which are more or less intermixed with the carbonates of lime, manganese, magnesia, and lead. Calamine occurs in veins in some of the old metamorphic rocks; in irregular masses in many of the sedimentary strata, as in the Mendip Hills, England; Tarnowitz, Silesia; Vieille-Montagne, and other places in Belgium; in Sardinia; in Siberia; and in Mexico.

Szaskaite, *Herrerite*, and *Kapnite* are varieties of calamine.

Barytocalcite. ($BaO.CO_2+CaO.CO_2$.)

This is an isomorphous mixture of the carbonates of baryta and lime. The crystals are elongated prisms, whose primitive form is an oblique rhombic prism, the principal faces of which are inclined towards each other at an angle of 106° 54′, and towards the base at an angle of 102° 54′. The cleavages are distinct parallel to the faces of the prism. The crystals are of a yellowish-white colour, and have a vitreous lustre. Their hardness is 4, and their specific gravity is 3·6 (40,140).

Natron. ($Na_2O.CO_2+10\,H_2O$.)

The anhydrous neutral carbonate of soda is not known in a native state, except perhaps in solution, but two of its hydrates are known. One of these is natron, which

crystallises in flat tables with bevelled edges, derivable from an oblique rhombic prism, whose principal faces are inclined at an angle of 79° 42′, and whose base is inclined to a vertical axis at an angle of 57° 40′. In nature, however, it seldom assumes the crystalline form, but nearly always that of a white or yellowish earthy in crustation. Its lustre is vitreous or dull, its hardness 1 to 1·5, and its sp. gr. 1·4 (15,649). It is soluble in both hot and cold water, and may be fused in its water of crystallisation at a moderate heat. It occurs, along with the monohydrated carbonate in the soda lakes of Egypt, Arabia, India, and Hungary. It has also been found at Vesuvius, at Etna, and in various parts of Asia, Africa, and America. In most cases it appears to have been formed by the action of carbonate of lime on common salt. The white efflorescence on old walls is frequently composed of this salt, and has been formed in the way indicated.

THERMONATRITE. ($Na_2O.CO_2+H_2O.$)

This is the monohydrated neutral carbonate of soda. It is usually associated with natron, being formed from it by efflorescence, and is frequently the more abundant of the two minerals. It is colourless, and has a vitreous lustre. It is fusible in the blowpipe, imparting to the flame the yellowish tinge characteristic of sodium. It crystallises in rectangular tabular crystals with bevelled edges, belonging to the trimetric system; the faces formed by the bevellings are inclined to the principal faces at angles of 85° 50′ and 107° 50′. It is found in Hungary, Lower Egypt, Columbia, and the East Indies.

TRONA. ($2\,Na_2O.3\,CO_2+4\,H_2O$, or Soda = 37·93; Carb. Acid = 40·24; and Water 21·83. *Syn.* Urao.)

It forms broad columnar crystals belonging to the monoclinic system, and derivable from an oblique rhombic prism of 47° 30′, having an easy cleavage parallel to the base. The crystals are colourless and transparent; they have a vitreous lustre, a conchoidal fracture, a hardness

of 2·5 to 3, and a sp. gr. of 2·6 (29,062). Trona has an alkaline and acid taste, does not effloresce in a dry atmosphere, and when exposed to a dry heat, or when its solution is boiled for a time, it is converted into the neutral carbonate ($Na_2O.CO_2$). It dissolves in dilute hydrochloric acid with effervescence. In nature it occurs most abundantly as an incrustation having a radiated fibrous structure. Near Fezzan, in North Africa, it forms a layer thick enough for it to be used in the construction of walls; it incrusts the ground at Maracaibo, in South America, where it is called *urao;* and it is found in an efflorescence near Sweetwater River, Rocky Mountains, mixed with sulphate of soda and common salt.

GAY-LUSSITE. ($Na_2O.CO_2+CaO.CO_2+5H_2O$. *Syn.* Natrocalcite.)

This combination of the carbonates of soda and lime crystallises in the monoclinic system in crystals derivable from an oblique rhombic prism, whose principal faces are inclined towards each other at an angle of 68° 50′, and towards the base at an angle of 96° 30′. The cleavage is perfect parallel to the faces of the prism. The crystals are white, vitreous, and transparent when pure, but by exposure to the air they often become yellowish white and opaque. The hardness varies from 2 to 3, and the sp. gr. from 1·92 (21,461) to 1·99 (22,224). When heated it loses its water and becomes opaque. It occurs in abundance at Lagunilla, near Merida, in Maracaibo, South America, and at Sangerhausen, in Thuringia.

LANTHANITE. ($\overbrace{La : Di}.O.CO_2+3H_2O$. *Syn.* Hydrocerite; Carbonate of Cerium.)

There has been, and still is, considerable uncertainty as to the composition of this mineral. First it was said to be a hydrated carbonate of cerium, next a hydrated carbonate of lanthanum, and now it is regarded as a hydrated carbonate of lanthanum and didymium. The crystals are thin tables with bevelled edges, and belong to the trimetric system. Their colour varies from greyish

white to faint pink, and their lustre is dull or pearly. The mineral is also found in earthy or finely granular masses. It forms a coating on cerite at Bastnäs, in Sweden; is associated with calamine at Bethlehem, in Pennsylvania; with magnetite and allanite at Moriah, Essex co., North America; and with zinc ores in the Silurian limestone of the Saucon valley, Lehigh co., Pennsylvania.

Liebigite. ($CaO.CO_2+UO.CO_2+10\,H_2O.$)

It is found in transparent apple-green amorphous masses, which break with a lustrous fracture. Its hardness is from 2 to 2·5. It is associated with *Medjidite* near Adrianople, in Turkey, and is also found at Johanngeorgenstadt, and in the Joachimsthal. A similar mineral, but containing less water, forms scaly incrustations on pitchblende at the Elias mine, Joachimsthal; and a third (*Voglite*) occurs in the same locality, which contains a small proportion of copper. *Uranocalcite* differs from Liebigite in its proportion of water.

Zinc Bloom. ($m\,ZnO.CO_2+n\,ZnO.H_2O.$)

The results obtained by different observers of the composition of this mineral have varied considerably, but they all conform to the general formula given above, which indicates that it is composed of variable proportions of carbonate and hydrated oxide of zinc. It occurs native in earthy and concretionary masses, which have a dull white or yellowish colour, a sp. gr. of 3·6 (40,140), and a hardness of 2 to 2·5. Its principal localities are at the mines of Bleiberg, in Carinthia, and of Sazka, in Hungary.

Emerald-Nickel.

A hydrocarbonate of nickel which occurs in emerald-green botryoidal incrustations on chrome-iron ore at Texas, in Lancaster co., Pennsylvania, and at Swinaness, in Unst, Shetland. It has a vitreous lustre, a hardness of 3 to 3·25, and a sp. gr. of 2·6 (29,062). A similar

mineral (*hydro-nickelmagnesite*) is found in the same localities which contains magnesium as well as nickel.

AGNESITE. (*Syn.* Bismutite.)

This is probably a hydrocarbonate of bismuth. It occurs in amorphous or semicrystalline incrustations of a yellowish or greenish colour at Heischberg in Voigtland, and at Schneeberg in Saxony.

HYDROMAGNESITE. ($m\,MgO.\,CO_2 + n\,MgO.\,2\,H_2O.$)

This is the same substance as the *magnesia alba* of the pharmaceutist, and the hydrocarbonate of magnesia of the chemist. It generally occurs native in earthy incrustations or nodular masses of a white colour, of a hardness of 1·5, and of a sp. gr. of 2 (22,356). The crystals, which are rare in the native state, are minute elongated prismatic needles, which are, according to Dana, derivable from a rhombic prism of 88°; they have a vitreous or silky lustre, a hardness of 3·5, and a sp. gr. of 2·14 (23,920) to 2·18 (24,368). Hydromagnesite is infusible before the blowpipe, and after it has been calcined behaves like common magnesia. It is found in serpentine, a rock composed mainly of silicate of magnesia, at Kumi, in the island of Negropont; at Hrubschitz, in Moravia; at Hoboken, in New Jersey; at Texas, in Lancaster co., Pennsylvania; and at Baldissero, in Piedmont. *Lancasterite*, *Predazzite*, *Pencatite*, and *Hydrodolomite* are varieties of this species. The first-mentioned has a considerable quantity of brucite mixed with it, and ought perhaps rather to be considered to be an altered brucite.

AURICHALCITE.

A native hydrocarbonate of copper and zinc, met with in transparent, verdigris-green, acicular crystals at Loktewsk, on the Altai Mountains. When reduced by the blowpipe it yields an alloy of copper and zinc resembling gold in colour.

CHESSYLITE. ($3\,Cu_2O.\,2\,CO_2+H_2O$, or Ox. Cop.=69·22; Carb. Acid = 25·56; and Water 5·22. *Syn.* Azurite; Lasurite; Blue Copper Ore; Blue Carbonate of Copper; Blue Malachite.)

This may be considered as a hydrocarbonate of copper. Its crystals belong to the monoclinic system, and are derivable from an oblique rhombic prism, whose faces are inclined towards each other at an angle of 99° 32′, and towards the base at an angle of 91° 48′. The cleavage is distinct parallel to the lateral faces of this prism. The native crystals are usually short, or even tabular, prisms, in which the faces corresponding to those of the primary form are striated, while the secondary faces are at once recognised by their higher polish and lustre. It is also found in masses, which have a lamellar, acicular, fibrous, pisolitic, compact, or earthy structure. The colour varies from azure blue (which is always the colour of the powder) to indigo blue; the fracture is conchoidal, the lustre vitreous, the hardness 3·5 to 4·25, and the sp. gr. 3·5 (39,023) to 3·8 (42,376).

It is generally associated with malachite, and is often found more or less converted into that mineral. It sometimes occurs in veins containing various copper ores, and sometimes in lumps and groups of crystals, in strata corresponding in age to the new red sandstone of England, as, for instance, at Chessy, near Lyons, from whence some of the finest crystals have been obtained. There are many other localities, but the more important are Wheal Buller, near Redruth, in Cornwall; Alston Moor; Moldavia, in the Bannat; Nischne Tagilsk, in the Ural Mountains; near Nicolaief and Kolywan, in Siberia; and in several parts of the United States and Australia.

MALACHITE. ($2\,Cu_2O.\,CO_2+H_2O$, or Oxide of Copper = 72; Carbonic Acid = 20; and Water = 8. *Syn.* Green Carbonate of Copper; Mountain Green; Atlas Ore; Atlasite.)

Malachite forms crystals belonging to the monoclinic system, and derivable from an oblique rhombic prism, with

the principal or lateral faces inclined towards each other at an angle of 103° 42′, and towards the base at an angle of 111° 48′. The crystals are comparatively rare in nature, and are generally tabular prisms; it is more often in the forms of cuprite and tetrahedrite, and most common in masses having a fibrous, botryoidal, reniform, compact, or earthy structure. The concretionary nodules vary in size from less than a quarter of an inch to one or two feet in diameter, and when broken they exhibit concentric bands of various shades following the curves of the surface, which is usually smooth. The colour varies from emerald to grass green, which is generally sufficiently deep to render the mineral opaque except in thin slices. The hardness is 3·5 to 4, and the sp. gr. 3·7 (41,258) to 4 (44,712). As it takes a high polish, and its concentric rings of dark and light green have a pleasing effect, it is much employed as a material for tables, vases, snuff boxes, and other objects. The finest specimens of the fibrous variety are obtained from the mines at Nischne Tagilsk and Goumeschefski, Siberia; it is also found in many of the copper mines of Saxony, Hungary, and Bohemia; at Chessy, in France; at Sandlodge, in Shetland; and at Burra Burra mines, in Australia. Other varieties have been found in Cumberland, Cornwall, the Tyrol, West Africa, and North America. *Mysorin* is probably an impure malachite, or it may be an anhydrous malachite. It is found at Mysore, in India.

PHOSGENITE. ($2\,PbCl_2 . PbCO_3$. *Syn.* Kerasine; Corneous Lead.)

This is probably the chlorocarbonate of lead, formed by the combination of the chloride with the carbonate of lead. The native crystals are rare, and are sometimes in the form of quadratic prisms, and sometimes in that of acute pyramids with a square base. The colour is yellowish or greenish white; the fracture conchoidal, the hardness 2·5 to 3, and the sp. gr. 6·1 (68,185). It has been found at Cromford, near Matlock, Derbyshire, associated with the carbonate and the sulphate of lead; in a lead mine

near Elgin, Scotland; at Tarnowitz, Silesia; Badenweiler, Baden; and Southampton, Massachusetts. It is occasionally pseudomorphous after cerusite, or the carbonate of lead.

Parisite. (*Syn.* Mussite; Mussonite.)

The formula for this mineral is exceedingly complicated. It is composed of the carbonates of cerium, lanthanum, and didymium, and of the fluorides of cerium and calcium. Its crystals are regular double hexagonal pyramids, having a basal angle of 164° 58′, a pyramidal angle of 120° 34′, and a distinct basal cleavage. The colour is brownish yellow in the mass, and yellowish white in the powder; the lustre is vitreous, except on the horizontal or cleavage faces, where it is somewhat pearly; the hardness is 4·5; and the sp. gr. 4·35 (48, 614). It is infusible by the blowpipe. Hydrochloric acid dissolves it slowly with effervescence. It is found in the emerald mines of the Muso valley, New Granada.

Thinolite.

This is a variety of calcareous tufa, differing from ordinary calcareous tufa in being crystalline, a circumstance due to its being a pseudomorph after gay-lussite. It occurs in great abundance in the deposits of the vast lakes which once existed in the more arid regions of the United States.

Gay-Lussite.

This compound is now forming beautiful crystals in the salt water of the Ragtown Ponds, near Carson, which represent the last dying-out remnants of fresh-water lakes of immense extent which once occupied this region. When these large lakes, named Lahontan, Bonneville, &c., had reached a certain stage of concentration, they deposited extensive layers of gay-lussite crystals, which have since lost their soda, and become converted into carbonate of lime.

Sphærocobaltite.

The formula is probably $CoCO_3$, or carbonate of cobalt. It occurs in spheroidal forms in roselite at Schneeberg, Saxony. The spheroids are coarsely radiated, and their surfaces are made up of minute rhombohedral crystals of a peach-red colour. The hardness is 4, and the sp. gr. 4 to 4·1. It blackens in the matrass before the blowpipe, and dissolves in warm hydrochloric acid with effervescence.

Hovite.

The bicarbonate of lime is only known in a state of solution, but some mineralogists are of opinion that it may be present in a hydrated form in a mineral which fills fissures in an old chalk quarry at Hove, near Brighton, where it is mixed with collyrite, one of the hydrated silicates of alumina, and the presence of which favours the stability of the bicarbonate.

CHAPTER VIII.

SILICATES.

Group I.—Silicates which do not contain Alumina as an essential element.

Willemite. ($2\,ZnO.\,SiO_2$, or Oxide of Zinc = 72·98; Silica = 27·02. *Syn.* Troostite.)

The crystals are very minute, and have the form of regular hexagonal prisms terminated by obtuse rhombohedral summits. It is fused with difficulty by the blowpipe, and is soluble in hydrochloric acid, with separation of gelatinous silica. The colour is yellowish or brownish red, the hardness 5·5, and the sp. gr. 3·9 (43,594) to 4·2 (46,947). It occurs abundantly at Moresnet, as also, though not abundantly, at Stolberg, near Aix-la-Chapelle; at Rachel, in Carinthia; and at a few localities in the

United States. *Troostite* is a variety containing manganese, and *Mancinite* is probably a variety.

PHENAKITE. ($2\,GlO.\,SiO_2$, or Glucina = 46·04; Silica = 53·96.)

There is some doubt as to the atomic weight of glucinum, and hence some uncertainty as to the correct formulæ for its compounds. Its crystals belong to the rhombohedral system, and are more or less modified from a rhombohedron with an angle of 116° 36′. It is nearly always crystalline, the predominant form being a regular hexagonal prism terminated by pyramidal summits, a form also presented by quartz; it further resembles quartz in the way in which the crystals are grouped together, in its fracture, and, indeed, in so many of its external characters, that it was formerly mistaken for hyaline quartz. The crystals are transparent and colourless, or wine yellow inclining to a pale rosy tint. The hardness is 7·5 to 8, index of refraction 1·65, and the sp. gr. 2·98. It is infusible before the blowpipe, but when heated along with the phosphorus salt it slowly dissolves, leaving a skeleton of silica; and when heated with a little carbonate of soda, it melts into a milk-white globule. Acids have no effect upon it. It is associated with the emerald at Takowaja, in the Ural Mountains; with topaz and a green felspar near Miask, in Russia; and with quartz at Framont, in Alsace.

OLIVINE. ($2\,\overbrace{Mg : Fe}.\,O.\,SiO_2$. *Syn.* Chrysolite; Peridote.)

It occurs in transparent crystals, to which the term *Chrysolite* is usually restricted, and in small grains in lava, basalt, and meteorites. The crystals belong to the trimetric system, and are modifications of a rectangular prism, with a tolerably easy basal cleavage. The colour is a pale yellowish green in the larger crystals, and olive green in the smaller ones, and in the granules found in basaltic rocks. Some of the varieties containing iron are

brown or even black, and become yellowish or reddish by weathering. The fracture is conchoidal, the lustre vitreous, the hardness 7, the sp. ht. ·187, and the sp. gr. 3·5 (39,023). The pure magnesian varieties are infusible by the blowpipe, but those containing iron are fusible. All the varieties are decomposed by hydrochloric and sulphuric acids. The ferriferous varieties are readily altered by air and water. It is usually met with in basaltic rocks, but has also been found in the talcose schists of Mount Itkul, near Katharinenburg; in the mica slate at Tissersk, in the Ural; in Upper Egypt; in Brazil; and probably the fine chrysolites which are brought from Constantinople were originally obtained in Eastern Asia.

There are numerous varieties: the commonest is *olivine* proper, which forms granular lumps and masses in basalts and lavas; by its alteration it gives rise to the varieties called *Limbilite* and *Chusite*. *Hyalosiderite* is a variety containing 30 per cent. of oxide of iron; *Boltonite* is a nearly pure magnesian chrysolite; *Forsterite* contains a small proportion of silicate of lime; *Monticellite* contains a larger proportion of the same silicate; and in *Batrachite* there are about equal proportions of the silicates of magnesia and lime. *Eulysite* contains nearly 9 per cent. of the protoxide of manganese. *Villarsite* is probably only an altered variety.

Fayalite. ($2\,FeO.\,SiO_2$.)

An iron chrysolite found in trimetric crystals in pegmatite (a granitic rock) on the Mourne Mountains, Ireland, and in the volcanic rocks of Fayal, one of the Azores. It is of an iron-black or greenish colour; the hardness is 6·5, and the sp. gr. 4·1 (45,829). It readily fuses into a magnetic globule, and is partially soluble in acids. Crystals having the form of chrysolite and the composition of fayalite are sometimes found in furnace slags.

AEDELFORSITE. ($2\,CaO.\,3\,SiO_2$. *Syn.* Edelforsite.)

A silicate of lime which occurs in massive, fibrous, or feathery masses; the colour is white or greyish; the lustre is vitreous, somewhat inclined to pearly or silky; the hardness is 5·5, and the sp. gr. 2·58 (28,839). It forms a clear glass when fused with the blowpipe, and gelatinises with acids. It is found in saccharoidal limestone at Aedelforss, in Sweden; at Gjelleback, in Norway; and at Cziklowa, in the Bannat. This name is also sometimes applied to a red zeolite usually called *Retzite*.

HUMITE. (*Syn.* Brucite; Maclureite; Chondrodite; Hemiprismatic Chrysolite.)

No formula can be given, since the minerals which constitute the species appear to be composed of variable proportions of two compounds. According to Rammelsberg, these compounds may be represented by the two formulæ:—

$$Mg_{16}\,Si_3\,F_{28} \text{ or } 8\,MgF_2\,3\,SiF_4 = A.$$
$$Mg_{16}\,Si_3\,O_{16} \text{ or } 8\,MgO\,3\,SiO_2 = B.$$

According to the proportions in which these are mingled they give rise to types or varieties marked by certain distinguishing characters. Thus, in ordinary chondrodite (Fig. 1, Pl. II.) the proportion is A + 12 B; in a second variety A + 18 B; in a third, A + 27 B; and in a fourth, A + 36 B.

All the crystals have three unequal axes, but the ratio of the axes is different in each variety, in consequence of the modified forms being derived from the primary form according to a different law. The ratios of the axes are as follows:—

	Macrodiagonal.		Brachydiagonal.		Primitive axis.
2nd var.	1·46	:	1	:	1·08
3rd var.	1·57	:	1	:	1·08
4th var.	1·41	:	1	:	1·08

Each variety has a different colour and sp. gr.; thus the second variety is white or pale yellow, and has a sp. gr. of 3·22 (35,893); the third variety is yellow, and has a sp. gr. of 3·19 (35,557); while the fourth is brown, and has a sp. gr. of 3·18 (35,446).

The hardness varies from 6 to 6·5. All agree in being fusible with difficulty at the edges by the blowpipe; in giving the reaction of fluorine when heated with sulphuric acid; in generally occurring in crystalline grains or granular masses; in dissolving in hydrochloric acid, with separation of gelatinous silica; in occurring in granular limestone; and in being associated with a greenish uniaxial mica. The first variety is found in Norway, Finland, and the United States. The others occur in the same countries, and also at Vesuvius.

Melinophane.

It resembles *Leucophane* in composition, but is generally separated from it, in consequence of its somewhat different physical characters. It occurs in crystals, and in masses having a laminar structure; it has an easy cleavage in one direction only. Its colour is sulphur or citron yellow; its lustre vitreous; its hardness 5; and its sp. gr. 3·0 (33,434). It is not phosphorescent. It is found in the zircon syenite of Norway. Richter's analysis of it gave 44·8 per cent. silica, 2·2 glucina, 12·4 alumina, 1·4 manganic oxide, 1·1 ferric oxide, 31·5 lime, 0·2 magnesia, 2·6 soda, 2·3 fluorine, and 0·3 nickel oxide, zirconia, ceric oxide, and yttria.

Leucophane.

It is a silicate of glucina and lime, and is usually found in columnar masses, but a few crystals have been discovered. They probably belong to the trimetric system. According to Des Cloizeaux, they are right rhombic prisms with an angle of 91°, and with imperfect cleavages in three directions, the most distinct being parallel to the base. It is transparent and colourless in thin slices, but pale or greenish yellow in the mass. The hardness varies from 3·5 to 4; and the sp. gr. from 2·97 (33,198) to 3 (33,534). It is optically biaxial, phosphorescent when struck, and electrically polarised when heated. It fuses before the blowpipe into a violet-coloured bead, and when heated with phosphorus salt gives the reactions of

fluorine. It is found in the zircon syenite on the island of Lamoe, at the mouth of the Langesundfjord, in Norway, where it is associated with elæolite, albite, and yttrotantolite.

GADOLINITE. (*Syn.* Ytterbyte.)

A mineral whose chemical composition and crystallographical form do not appear to have been accurately determined. It may be regarded probably as a silicate of yttria (3 YO. SiO_2), usually mixed with other silicates. It is generally amorphous, and the few crystals hitherto found have in most cases been distorted. Apparently they are derivable from an oblique rhombic prism whose vertical faces are inclined towards each other at an angle of about 115°. The amorphous masses resemble obsidian in having a black colour, a vitreous lustre, and a conchoidal fracture. The colour of thin plates by transmitted light is bottle-green, and the powder is greyish green. The hardness varies from 6 to 6·5, and the sp. gr. from 4 (44,712) to 4·35 (48,614). When heated by the blowpipe it fuses on the edges, but the bulk of the mass suddenly becomes incandescent, the density somewhat greater, and the colour lighter. Before calcination it is soluble in hydrochloric acid, with separation of gelatinous silica; but after calcination it is insoluble in this acid. Its optical properties are variable; and according to Des Cloizeaux, the various specimens of gadolinite may be arranged in three groups, each group having its own peculiar optical properties. The three groups he would refer to two distinct species. Gadolinite is found in granites and pegmatites at various localities in Norway and Sweden; amongst others, Finbo, Ytterby, and Hitteroe.

ENSTATITE. (Mg SiO_3, or Silica = 59·71; Magnesia = 40·29.)

A silicate of magnesia which was formerly confounded with scapolite, but is at once distinguished from it by its infusibility by the blowpipe. It is also essentially distinct from *Pyrallolite*, which is a hydrated silicate of magnesia,

and an alteration product of augite. Enstatite is anhydrous when pure. Its colour varies from greyish white to slightly greenish or yellowish. Its crystals are derived from a rhombic prism in which the angles are 93° and 87°. It cleaves most easily along planes parallel to the prism of 93°; while other cleavages occur parallel to the diagonal section of the same prism. The hardness is 5·5, and the sp. gr. 3·12 (34,775). When pure, it is colourless and free from iron as in the variety called *Victorite*, found in the meteoric iron of Deesa. When protoxide of iron replaces a portion of the magnesia, the tints become greenish and brown, and as the proportion increases we pass on to specimens with a bronzy lustre. These form the variety *Bronzite*, which in the typical specimens contains 40 per cent. of magnesia, and 10 per cent. of protoxide of iron, with a sp. gr. of 3·2, or somewhat greater than that of enstatite. Enstatite is found crystallized in the serpentine of Mount Zdjar, near Aloysthal, in Moravia, where it is associated with pseudophite; and at Mount Bezouars, in the Vosges.

HYPERSTHENE. ($\overbrace{Mg : Fe.}\ SiO_3$. *Syn.* Paulite; Labrador Hornblende.)

It is a silicate of iron and magnesia, intermediate between enstatite and grünerite. These three minerals are more or less connected by varieties which tend towards pure silicate of lime on the one hand, and pure silicate of iron on the other. It forms the essential ingredient of the rock called *hypersthenite*, in which it occurs in flaky masses, having a greenish-black or black colour, a vitreous or pearly lustre, and a copper-coloured reflection or iridescence on the planes of easiest cleavage. This iridescence is attributed to the presence of microscopic plates of titaniferous iron. The masses of hypersthene cleave into rhombic prisms with an angle of 93° 30′, and therefore isomorphous with the primary form of enstatite. The hardness is 6, and the sp. gr. is 3·4 (30,005). When fused by the blowpipe, it yields a black enamel which is frequently magnetic. It is found in the island of St. Paul,

on the coast of Labrador; in Canada; in the United States; in the Isle of Skye; at Hitteroe, in Norway; at Penig, in Saxony; and in the Breitenbach meteorite.

Anthophyllite should, perhaps, be considered a variety of hypersthene, rather than a species distinct from it, and would include the specimens in which the magnesium predominates over the iron. It occurs in masses having a fibrous structure, and cleavable in rhombic prisms of 125°. Its optical characters seem to indicate that the primary prism has an angle approaching a right angle, similar to that of hypersthene. The colour is greyish brown; the lustre submetallic; the hardness 5·5; and the sp. gr. 3·2. It is found in mica schist at Kongsberg, Norway; Helsingfors, Finland; Cummington, Massachusetts; Perth, in Canada; and Tkertoak, in Greenland. *Gedrite* would include the specimens in which the iron predominated over the magnesium.

DIOPSIDE. ($\overline{Ca : Mg}\ SiO_3$ or $\overline{Ca : Mg}O.\ SiO_2$.)

This is a lime-magnesia augite, which is transparent and colourless when pure, as in the case of the variety called *alalite*, from Ala, in Piedmont. Generally, however, it is coloured by the protoxides of iron and manganese. The crystals are doubly refractive, and the coloured ones usually exhibit decided dichroism. The faces of the primary prism are inclined towards each other at an angle of 87° 6′, and the most distinct cleavages are parallel to these faces. The crystals are frequently distorted or elongated, are often striated in a longitudinal direction, and sometimes exhibit a scaly or fibrous structure in their interior. This latter appearance is very similar to that of the asbestiform tremolite. One of the forms of diopside is shown in Fig. 45. The colour, when present, is generally light green, but varies from yellowish white to greenish grey and light grey. The lustre is vitreous on the natural faces of the crystal, but pearly on those produced by cleavage. The hardness is 5·5, the sp. ht. ·186, and the sp. gr. 3·2 (35,667) or 3·3 (36,777).

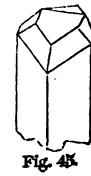

Fig. 45.

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Diopside is fusible before the blowpipe into a colourless, or almost colourless, glass, and is insoluble in acids. There are several varieties distinguishable by slight differences of colour and texture; thus, white *Coccolite* occurs in saccharoidal limestone in numerous European and American localities, in grains compressed together, and associated with calcspar and scapolite. *Mussite* forms translucid or opaque greenish prismatic crystals in serpentine at Mussa, in Piedmont; *Traversellite* forms large dark green prisms, longitudinally striated, near Traversella, Piedmont; and the *asbestiform diopside* derives its name from the loosely-aggregated parallel fibres of which it consists. This last variety is frequently called asbestos, a name which should, however, be restricted to the corresponding asbestiform variety amongst the hornblendes.

There is also a group of minerals which may be conveniently mentioned here. They resemble diopside in chemical constitution, crystalline form, and in most of their physical properties, but generally they contain a considerable proportion of ferrous oxide, which replaces a corresponding proportion of the lime and magnesia. The light green *Sahlite* is perhaps the type of this group, which also includes the green *Malacolite* of Arendal, in Norway; the olive-green *Baikalite* of Lake Baikal, in Siberia; the yellowish-green *Fassaite* of the Fassathal; the sombre green *Pyrgomme* and *Protœite* of Mount Monzoni, in Tyrol; the grass-green *Omphazite* of Bayreuth; the emerald-green *Sahlite* of Willsborough, in the United States; the dark green, or almost black, *Hedenbergite* of Tunaberg, in Sweden; and a few others. The omphazite is always associated with garnet, and with it forms the rock called *eklogite;* it is sometimes considered to be a variety of *diallage.* Hedenbergite is also ranked as a variety of *grünerite.*

Diallage.

This species, if it can be considered a species, has not been very accurately defined, the difficulty being its gradual merging into allied minerals. The term is generally

applied to certain greyish-green crystals and laminæ, which contain about equal proportions of lime and magnesia combined with silica; by an increase in the proportion of lime it passes into diopside; and by an increase in the magnesia it passes into *diaclasite*, which is probably only a partially decomposed hypersthene. Diallage is also richer in protoxide of iron than diopside. It forms small laminæ sometimes in jade, and sometimes in serpentine. In the first case, which is most frequent, it becomes an essential ingredient of diallage rock and euphotide.

GRÜNERITE. ($Fe\ SiO_3$.)

This is a nearly pure iron augite, found at Collobrières, in the department of the Aude, France. It is of a greyish colour, asbestiform, and with a sp. gr. of 3·7 (47,258).

AUGITE, or BASALTIC AUGITE.

This is a silicate of lime, magnesia, and iron, and is usually of a dark green or black colour. It sometimes contains alumina, which in some specimens amounts to 12 per cent. It contains more iron than most of the other augites, and hence its colour is also darker. It forms short and well-defined crystals (Fig. 46) in such rocks as basalt, dolerite, black porphyry, or melaphyre, and also in many lavas. Many of these rocks are largely composed of augite in a non-crystalline state. For example, dolerite is a mixture of labradorite and augite, in which the proportion of the latter may vary from 10 to 40 or 50 per cent. It also enters largely into leucite rock and lherzolite. In some diorites, such as those of the Ural Mountains, the augite crystals are more or less altered into hornblende; these have been named *Uralite*. *Pitkarandite* is another variety of a similar character.

Fig. 46.

There are several other minerals which might be referred to the augite family, such as *Breislakite*, *Seladonite*, *Ægyrin*, *Violan*, and *Achmite*; but it does not seem necessary to dwell upon them here.

The minerals which follow after gadolinite form a group known as the augite group, whose species are closely connected together. This relationship, according to Rose, consists in all the species being completely isomorphous amongst themselves, and at the same time isomorphous with the corresponding species of the hornblende group as regards their crystalline structure, but not so as regards their chemical composition. Later chemists, however, have concurred with Rammelsberg in believing that all the species of both groups may be expressed by the same general formula, and consequently that they possess both chemical and crystallographical isomorphism. Whether Rammelsberg's hypothesis be correct or not, the remarkable differences presented by the species of the two groups render it most convenient at present to keep them separate in our descriptions. The augites are chemically regarded as metasilicates; that is, silicates capable of being reduced to the general formula $D\,SiO_3$, in which D stands for one atom of a diatomic metal (or two atoms of a monatomic metal), generally lime or magnesia, and less frequently the protoxides of iron and manganese, which may replace the former in every proportion. This is the normal composition; but there are species which contain a larger proportion of silica than indicated in the formula, and also a considerable proportion of sesquioxides, such as alumina and peroxide of iron. The presence of these ingredients appears inconsistent with the view propounded by Rammelsberg, and some chemists have endeavoured to meet the difficulty by supposing that alumina may be isomorphous with, and may consequently take the place of, the silica. M. Charles Deville, on the other hand, suggests that such species may be mixtures of a normal augite with an aluminate.

The augites are distinguished from the hornblendes by the cleavage planes being parallel to the vertical faces of the primary prisms, and consequently at an angle of about 87°; by fusing at a higher temperature; by their vitreous appearance; and by their less brilliant lustre. The cleavages are less perfect in augite than in hornblende. Another

distinctive point is that the augites cleave in a direction parallel to their base, whereas the hornblendes do not. This character is not a convenient one, since many augites and hornblendes which are composed of thin laminar crystals appear to cleave in this direction; but in such cases the planes are planes of separation, not planes of cleavage. There is also a difference in the mode of crystalline development; for, although theoretically it is true that all the forms of crystals yet met with in augites and hornblendes may be derived, according to certain definite crystallographical laws, from the same primary form, yet practically the actual crystalline forms of augites have not been met with amongst the hornblendes. The optical properties of the crystals of the two groups are strikingly different, as also is their stratigraphical distribution; for, generally speaking, the hornblendes are found in the plutonic rocks, and the augites in those of volcanic origin. There are rocks in which minerals belonging to both groups have been met with.

The hornblende group resembles the augite group in having light and dark varieties; the white varieties consist of silicates of lime and magnesia, with scarcely a trace of iron; but both the light and dark-coloured hornblendes contain less lime than augites of the same colour. The crystals obtained by cleavage are oblique rhombic prisms with an angle of about 125°.

TREMOLITE. ($\overline{Ca : Mg}$ SiO_3. *Syn.* Grammatite.)

This is a lime-magnesia hornblende, corresponding with diopside amongst the augites. The pure crystals are white, but the impure ones are yellowish, or greenish grey, owing to the presence of protoxide of iron. When the quantity exceeds 3 or 4 per cent., the colour is asparagus green, as in the variety called *Calamite;* when the quantity is still greater, the mineral belongs to actinolite. They are doubly refractive. They usually occur as long slender needles abruptly terminated, as though fractured; but sometimes the mineral forms radiated masses of a silky aspect. The lustre is vitreous, approaching to

pearly; the hardness is 5·5; and the sp. gr. 2·9 (33,016). It is readily fusible by the blowpipe into a colourless glass, and is insoluble in acids. There are several varieties of tremolite. Thus, the substance known as *asbestos* and *amianth* is in most cases tremolite containing a little water. It generally occurs in fine fibres, which may be isolated or packed closely together with their principal axes parallel. It has a silky lustre, and is sufficiently tough and flexible to be woven into a kind of cloth, capable of resisting intense heat without burning or fusing. It was known to the Romans, who used it for covering bodies burnt in the funeral pile in order to keep their ashes distinct. It is, or has been, employed for many purposes, such as wicks for lamps, fire-proof gloves and napkins, linings for safes, &c. *Mountain leather* is a similar mineral, but the fibres are finer, closer, and intermixed. *Mountain cork* is a spongy, elastic asbestos, with the fibres interlaced together. *Mountain wood* is like the last, but denser, far less elastic, and capable of taking a high polish: sections of it somewhat resemble silicified wood. These varieties commonly occur as threads and in drusy cavities in the crystalline rocks, such as granular limestones, serpentines, and euphotides. They are usually associated with quartz, axinite, adularia, epidote, albite, and are found in the Swiss Alps, the Pyrenees, Greenland, the United States, Sweden, Silesia, New South Wales, and many other countries. Fine specimens of mountain wood have been brought from Sterzing in the Tyrol, and a few localities in Savoy and Piedmont.

Nephrite, or oriental *jade*, is a compact variety much used by the Chinese as a figure stone. The colour is sometimes light green, as in the *white jade;* and olive green, as in the *green jade.* It has an uneven, fine-grained fracture, like that of some specimens of petrosilex, and a greasy lustre like that of some serpentines. Its toughness is considerable, a property which has probably had much influence in causing it to be used as a war implement. The war hatchets, or *poenamu* of the New Zealanders, and the Amazon stone of the South

Americans, are simply nephrite. It has been lately found in considerable quantity in the valleys of the Karakash and Amur, as also in several other localities of Central Asia. *Koksharowite* also seems to be a variety.

Tremolite is found at a multitude of places, but nearly always in the older dolomites and saccharoidal limestones.

ACTINOLITE. $(\overset{\cdot}{\overbrace{Mg : Ca : Fe}}\ SiO_3$. *Syn.* Actinote; Strahlstein.)

Under this name are included all the lime-iron-magnesia hornblendes containing little or no alumina. They crystallise in slender acicular prisms of a greenish colour, more or less tinged with yellow, brown, and black. They are commonly found in the talcose and micaceous rocks at St. Gothard, at Greiner in the Tyrol, at Ehrenfriedersdorf in Saxony, at Arendal in Norway, and other places. Actinolite is sometimes intimately associated with various sulphides, such as copper pyrites, iron pyrites, and galena. Near Gründstadtel, in Saxony, it has been found in small dykes in limestone along with chlorite, blende, malachite, copper pyrites, &c. It is associated with asbestos, quartz, cat's-eye, axinite, and thulite in serpentine. Amongst its varieties are included the darker specimens of *Calamite* and *Byssolite*, which occur in green or brown capillary needles in Dauphiny, Savoy, Switzerland, and Tyrol. *Raphilite* is an asbestiform variety from Lanark, in Canada.

HORNBLENDE.

Common hornblende embraces the various lime-iron-magnesian varieties which contain alumina, and generally a larger proportion of protoxide of iron than in actinolite. Its crystals are dark green, or even black, in colour, short and perfect in form, so that they correspond with the crystals of common augite. Its hardness is 5·5, and its sp. gr. varies from 3 (33,534) to 3·4 (38,005). It is an important ingredient in many rocks, in which it

occurs in lamellar, globular, or fibrous masses. In some of the trachytes, basalts, and modern lavas, it is nearly always in isolated crystals; it enters largely into the composition of syenite, diorite, gneiss, and porphyry; and it forms the great bulk of hornblende schist and hornblende rock. The character of the hornblende is not precisely the same in the different rocks. Thus, in trachyte it is black, and rarely blackish green; the crystals are distinct, long, and even terminated at both extremities; they have a strong lustre, and a well-developed lamellar structure. In granite it is dark green, and never black; it presents a comparatively feeble lustre, and has the lamellar structure but slightly developed. Amongst the varieties may be mentioned *Pargasite*, from the saccharoidal limestone of Pargas in Finland, and from Phipsburg and Parsonsfield in Maine. Some mineralogists have regarded it as a distinct species, in consequence of some differences in its optical properties as compared with common hornblende. *Carinthine* is a variety from the Saualpe in Carinthia, which contains a small proportion of soda and potash.

Hornblende is alterable by nearly all infiltrating waters, and is frequently pseudomorphosed into talc, steatite, serpentine, chlorite, mica, limonite, and magnetite.

Arfwedsonite.

A soda-iron hornblende of a black colour in the mass, and green in the powder, of a lively lustre and with a cleavage of about 124°. It is easily fused, melting readily in a candle flame, and giving rise to a magnetic globule. It is not soluble either in acids or potash. It is found in a schist in Greenland associated with sodalite, eudialite, and orthoclase; in the zircon syenite of Norway, and in the magnetic iron deposits of Arendal.

Wollastonite. ($CaSiO_3$ or $CaO.SiO_2$. *Syn.* Table Spar.)

It occurs in white, vitreous, soft, lamellar masses, which readily cleave into rhombic prisms with an angle

of 86°, and with pearly-lustred cleavage planes. In some specimens the colour is yellowish or reddish. It has a hardness of 4·5, a sp. ht. of ·178, and a sp. gr. of 2·8 (31,298). It fuses before the blowpipe into a semi-transparent glass, and is dissolved by hydrochloric acid with separation of gelatinous silica. It is found in several of the older crystalline rocks, as also in some of the modern volcanic lavas. The principal localities are Cziklowa and Oravitza, in Hungary; Perheniemi, in Finland; Capo di Bove, near Rome; and Mourne Mountains, Ireland.

RHODONITE. (*Syn.* Manganese Spar; Rose Manganese; Paisbergite.)

This is a silicate of manganese which is rarely found in crystals, the usual form being laminated or granular masses which possess two cleavages inclined towards each other at an angle of 87° 38′. The hardness is 5·5, and the sp. gr. 3·6 (40,140). In the reducing flame of the blowpipe it gives rise to a red glass, and in the oxidising flame to a black metallic globule. The purest varieties are obtained at Langbanshytta and Paisberg, near Philipstadt, in Sweden; at Przibram, in Bohemia; at St. Marcel, in Piedmont; and at Franklin, in New Jersey, America. The variety from Paisberg sometimes contains lime, and has been called *Paisbergite;* that from Franklin contains oxide of iron and zinc, and has been called *Fowlerite.* The less pure varieties are *photizite* and *allagite,* which contain a little carbonate of manganese; *hydrophite,* which contains water; *heterocline,* or *marceline,* which contains oxide of manganese, and, although mentioned here, seems rather to be a variety of *Braunite; Bustamite,* which contains lime; and *stratopeite.*

BABINGTONITE.

A silicate of iron and lime which occurs in triclinic prisms, having the base and the lateral faces inclined at an angle of 92° 34′. Their general form and aspect considerably resemble those of some varieties of augite. The colour is dark greenish black, the lustre vitreous, the

fracture imperfectly conchoidal, the hardness 5·5, and the sp. gr. 3·4 (38,005). With the blowpipe it fuses into a magnetic dark-coloured globule, and is slowly decomposed by hydrochloric acid. It has been found near Tongue and Portsoy; at Arendal, in Norway, where it is associated with albite, red orthoclase, and hornblende; at Gouverneur, in New York State; and at Athol, in Massachusetts.

APOPHYLLITE. (*Syn.* Ichthyophthalmite, Fish-eye Stone.)

A hydrated silicate of lime and potash. The formulæ assigned to it are very various and complicated; but the theoretical composition, according to Bischof, is 52·43 per cent. of silica, 25·86 of lime, 5·36 of potash, and 16·35 of water. It is generally colourless and transparent, but is sometimes tinged with red, rose, green, or blue. The crystals are square prisms belonging to the dimetric system: they have a peculiar pearly lustre, which has obtained for them the name of *fish-eye stone*. Their hardness is about 4·5, and their sp. gr. 2·3 (25,699). When heated before the blowpipe it loses its transparency, exfoliates, froths up, and melts into a globule. It is soluble in hydrochloric acid, with separation of gelatinous silica. When partially decomposed, it becomes of an opaque white colour, and in this form has been called *Albin*, which is found in a phonolite at Marienberg, in Bohemia. *Oxhaverite* is a variety from Oxhaver, in Iceland. The transparent crystals are remarkable for their optical properties, which, according to Brewster, show that each crystal is built up of a number of small symmetrically-arranged parts. Many specimens contain fluorine, and Rammelsberg suggests that the mixture of the fluoride with the silicate may partially account for the variations in the optical properties of this mineral. It occurs in metalliferous deposits at Hellesta and Utoe, Sweden; at Andreasberg in the Harz, and at Orawitza and Cziklowa in Hungary; in amygdaloidal rocks in Bohemia, the Tyrol, the Faroe Isles, Disco Island, Greenland, and in the

Isle of Skye; and in basaltic conglomerates at Puy de la Piquette, in France.

Gyrolite, or Gurolite.

It occurs in spherical concretions, having a pearly lustrous lamellar structure, and a hardness of between 3 and 4. It resembles apophyllite in its behaviour before the blowpipe and in most of its physical characters, as well as in its chemical composition. Apophyllite is a hydrated silicate of lime and potash, while gyrolite is a hydrated silicate of lime. The theoretical composition of the latter is 52·18 per cent. of silica, 32·26 of lime, and 15·50 of water. In Annapolis County, Nova Scotia, crystals of apophyllite are sometimes found with gyrolite on the surface, and with gyrolite and calcite occupying cavities in their interior.

Okenite.

This mineral is very closely allied to gyrolite, and like it is a hydrated silicate of lime. It is usually found in fibrous masses, and the few crystals as yet discovered appear to have been prisms with the vertical faces inclined towards each other at an angle of 122° 19′. The colour is yellowish or bluish, the lustre pearly, the hardness 5, and the sp. gr. 2·3 (25,699). Its behaviour before the blowpipe and with hydrochloric acid scarcely differs from that of apophyllite. It is found in the amygdaloidal rocks of Faroe Islands, Iceland, and Greenland.

Pectolite. (*Syn.* Osmelite.)

A hydrated silicate of lime and soda occurring in semi-transparent crystals analogous to those of wollastonite, and also in fibrous, radiated, and stellar masses. Some specimens found in Ayrshire have had columns 3 ft. in length. The crystals are rhombic prisms with perfect cleavage parallel to its vertical faces, which are inclined towards each other at an angle of 95° 25′. The lustre is silky or vitreous on the fractured surfaces, the colour white or grey, the hardness 5, and the sp. gr. 2·68 (29,957) to 2·74 (32,717). It fuses before the blowpipe into a colourless

glass, and when subsequently treated with hydrochloric acid, yields gelatinous silica. Its localities are Castle Hill, Edinburgh, associated with wollastonite and prehnite; Knockdolian Hill, Ayrshire; Talisker, Isle of Skye; Langbans iron mine, Wermland, associated with chlorite and calcite; Monte Baldo, Upper Italy; Mount Monzoni, in the Tyrol; Isle Royal, Lake Superior; and Bergen Hill tunnel, New Jersey. The *stellite*, from Kilsyth, Scotland, is probably the same mineral.

Chlorophæite.

Chemically it is a hydrated silicate of iron; it has a dark green colour, a subresinous lustre, a hardness of 1·5 to 2, and a sp. gr. of 2 (22,356). It forms small earthy lumps in the cavities of amygdaloidal rocks of the Hebrides, the Faroe Isles, Fifeshire, and the neighbourhood of Newcastle-upon-Tyne; as also in the drusy cavities of basalt, diorite, and porphyry. *Chlorophœnerite* is a similar compound from Weissig, in Saxony; but it differs in having a sp. gr. of 2·68 (29,957), and a larger proportion of silica.

Meerschaum. (*Syn.* Sea Foam.)

It is a hydrated silicate of magnesia, which has as yet only been found in an earthy state. Some specimens may be represented by the formula $2\,MgO.\,3\,SiO_2+2\,H_2O$, and others by $2\,MgO.\,3\,SiO_2+4\,H_2O$. It is compact, smooth to the touch, slightly plastic, and sufficiently soft to be marked by the finger-nail. It has an opaque white colour, more or less tinged with yellow or red. When exposed to the blowpipe flame, it fuses on the edges only with considerable difficulty, but it is readily reduced to the liquid condition when treated along with borax. Hydrochloric acid dissolves it with separation of gelatinous silica. It is found in a thick band, in the midst of a chalk with flints, near Eski-Scher, in Anatolia, and from this band is obtained most of the material used for the manufacture of the pipes sold in Constantinople. Other deposits are known in the Isle of Negropont; at Vallecas, near Madrid; at

Salinelle, St. Ouen, and Coulommiers, in France; at Hrubschitz, in Moravia; and in Morocco. It has also been found abundantly in New South Wales, forming beds in the coal measures.

Talc.

A hydrated silicate of magnesia, from which the water is only driven off at a high temperature. It usually occurs in foliated laminar masses, like mica, which show indications of being made up of rhombic prisms with the vertical faces inclined towards each other at an angle of 120°. It differs from mica in not being elastic, in being softer and readily marked by the nail or mica, in yielding an unctuous-feeling powder, and in not containing alumina as an essential ingredient. The laminated variety of talc is adopted by mineralogists as representing 1 in the scale of hardness; its sp. gr. is 2·7 (30,180). The colour is white, sometimes tinged with green, and the lustre pearly. When heated in a matrass, it undergoes no appreciable loss of water or transparency; when subjected to a high heat, it exfoliates and hardens, but does not melt. Acids have no effect upon it either after or before ignition. There are numerous varieties, such as the *laminated* talc, which yields thin flakes capable of being easily bent; *lamellar* talc, in which the flakes are comparatively thick; *fibrous* and *pulverulent* talc. *Potstone* is a mixture of talc, chlorite, and tremolite. It has an opaque grey or greyish-green colour, and a somewhat slaty structure. The strongest heat has little or no effect upon it. As it is soft and easily moulded when first quarried, hardens when exposed to the air, remains unaltered by high temperatures or dilute acids, and not liable to impart any bad taste or quality to food, it forms an excellent material for ovens, stoves, teapots, and other objects. When greasy and dirty, it is readily cleaned by heating it to redness.

The finest specimens are brought from Greiner, in the Zillerthal, Tyrol; at St. Gothard, in the valley of Chamouni; at Sala and other localities in Sweden; in Siberia, Scotland, and other countries. *Potstone* is quarried in

various parts of Italy: for instance, near Chiavenna; at Val Sesia, near Monte Rosa; and is also found in Greenland, Saxony, United States, &c.

STEATITE has the same chemical composition as talc, and generally speaking the same physical properties. It is less crystalline in its character, although thin sections show evidences of crystalline structure when examined under a microscope with polarized light. It is remarkable for displacing other substances, retaining their forms without preserving their internal structure. Amongst the minerals which are thus displaced are topaz, spinel, quartz, bitterspar, staurolite, felspar, augite, hornblende, garnet, &c. It occurs in many of the more highly crystalline rocks, such as granite, gneiss, and serpentine; in drusy cavities of amygdaloidal rocks; and in metalliferous lodes. Like talc, it has its fibrous, lamellar, and earthy varieties. The lamellar variety is quarried and employed for various purposes; thus, it is mixed with clay in order to increase the translucency of the finished porcelain; when powdered, it is used for diminishing the friction of machinery, and as a basis of the coloured cosmetic powders. Pencils are made from it for removing grease from silks and cloths, and for marking out the patterns of clothes.

PICROSMINE is a hydrated silicate of magnesia from the iron mine of Pressnitz, in Bohemia. It readily yields by cleavage right rhombic prisms with the vertical faces inclined towards each other at an angle of 117° 48′. Its colour is white or greenish grey; its lustre pearly on the cleavage faces, and vitreous on the other faces; the hardness is 2·5 to 3, and the sp. gr. 2·59 to 2·68 (29,957). Its chemical formula is probably $2\ Mg\ SiO_3 + H_2O$.

PICROPHYLL is a hydrated silicate of magnesia which contains nearly 7 per cent. of protoxide of iron. It is found in deep greenish-grey foliated masses at Sala, in Sweden, having a hardness of 2·5, and a sp. gr. of 2·75 (30,739). When heated in the blowpipe flame, it is first blackened, then becomes white, but remains unfused.

Hydrophite. (*Syn.* Jenkinsonite.)

A hydrated silicate of magnesia and iron found in dark green fibrous masses at Taberg, in Sweden, and O'Neil's Mine, Orange County, New York. It has a feeble lustre, a sp. gr. of 2·46 (27,497) to 2·65 (29,621), and a hardness of 3·5.

Gymnite.

A hydrated silicate of magnesia, which differs from picrosmine in containing a much smaller proportion of silica, and a much larger proportion of water. It has as yet only been found in an amorphous state. The colour is yellowish, greenish, or reddish; the hardness 2 to 3·5; and the sp. gr. 2·2 (24,591). Its localities are at Middlefield, Massachusetts, associated with serpentine; in Texas County, Pennsylvania; at Bare Hills, Maryland; and in the Tyrol.

Serpentine.

This also is a hydrated silicate of magnesia, and differs little from gymnite in chemical composition. It contains a little more magnesia and a little less water. It is doubtful whether it should rank as a species. It is a compact tough substance, breaking with a splintery, or occasionally a fibrous fracture. The more fibrous varieties are called serpentine, asbestos, or chrysotile. Its colour, which comprises various tints of red, green, and brown, is due to the presence of a small proportion of protoxide of iron. When the tints are bright, and the mineral translucent, it is known as precious serpentine, while the more opaque and darkly-coloured varieties form the common serpentine. It is remarkably constant in its chemical composition, being generally composed of about 43 per cent. of silica, 44 of magnesia, and 13 of water. The hardness is about 3, and the sp. gr. about 2·5 (25,945). It gives off water when calcined; is infusible, except on the edges, by the blowpipe; and when exposed to a continued heat it whitens and hardens. It is soluble in hydrochloric and sulphuric acids, without separation of gelatinous silica. There are many varieties, such as *marmalite*, or the lamellar variety:

noble serpentine; common serpentine; *chrysotile*, *baltimorite*, or the asbestiform varieties. *Thermophyllite*, *vorhauserite*, and *picrolite* are also varieties. *Antigorite* is a laminated variety from the valley of Antigoria, Switzerland, which is doubly refracting and dichroic, being brownish green by reflected and leek-green by transmitted light. Crystals of serpentine are known, but they are probably always pseudomorphs of hornblende, augites, &c. It is disseminated through many rocks in broken masses, plates, and veins, and very frequently forms thick strata and high ranges of hills. In this latter case it becomes a rock.

Dermatin, or Dermatite, is a hydrated silicate of iron and magnesia, containing 2 atoms of water, about 40 per cent. of silica, and about 14 of protoxide of iron. It is found in dark green reniform masses at Waldheim, in Saxony. It is probably an altered serpentine.

Bastite, or Schillerspar, is regarded by many mineralogists as a crystalline variety of serpentine. It occurs in masses having some approach to crystallisation, and cleaving in two directions inclined towards each other at an angle of 87°. This last character seems to indicate its relationship to the augite group. The colour is leek-green tinged with yellow or brown, the hardness 3·5 to 4·0, and the sp. gr. 2·6 (29,062) to 2·8 (31,298). A strong heat causes it to become pinchbeck-brown and magnetic, and to fuse at the edges. Hydrochloric acid partially dissolves it, but sulphuric acid entirely.

Cerite. (*Syn.* Cererite.)

It is usually found in amorphous masses, and rarely in six-sided prisms. It appears to be a hydrated silicate of cerium; but in all the specimens hitherto examined, the oxide of cerium has been more or less replaced by the protoxides of lanthanum, didymium, iron, and lime. The colour is reddish violet or brownish red, the lustre almost adamantine, the hardness 5·5, and the sp. gr. 4·9 (54,772). It gives off water when heated by the blowpipe, acquires

a yellow tint, but does not fuse. When mixed with borax and heated in the oxidising flame, it yields a glass which is orange when warm, and yellow when cold. It is the principal cerium ore, containing about 60 or 70 per cent. of the oxide of cerium. It is found in an abandoned copper-mine at Bastnaes, near Riddarhytta, in Sweden, where it forms small beds in gneiss associated with cerusite, hornblende, mica, and copper pyrites.

Thorite.

A hydrated silicate of thorina which has not yet been found in a pure state, but, according to Berzelius, it is composed of 18·98 per cent. of silica, 57·91 of thorina, and 9·50 of water; it usually contains variable proportions of the protoxides of iron, uranium, and manganese in place of the thorina. The colour is black, and the sp. gr. 4·7 (52,536). When heated in a matrass it gives off water and turns brown; it is infusible by the blowpipe, and dissolves in hydrochloric acid with separation of gelatinous silica. *Orangeite* is a variety of thorite of an orange-yellow colour, and containing somewhat less water.

Tritomite is a brown mineral found in small regular tetrahedrons in a syenite at Lamoë, near Brevig, Norway. Its hardness is 5·5, its sp. gr. 4·5 (50,301), and its chemical composition undetermined, but it appears to be a hydrated silicate of cerium allied to Thorite.

Smithsonite. ($2\ ZnO\ SiO_2 + H_2O$. *Syn.* Electric Calamine; Calamine of Beudant.)

A hydrated silicate of zinc, far more commonly found in lamellar, concretionary, or cavernous masses than in crystals. The latter belong to the trimetric system, and are, like those of tourmaline, hemihedral modifications. The primary form is a rhombic prism with an angle of 104° 13′, with perfect cleavage parallel both to the faces and base of the prism. The crystals are transparent and colourless when pure, frequently striated in a longitudinal direction, and strongly electric when heated; indeed, the change of temperature required to render them electric

is so slight that they are nearly always in a state of electrical polarity. They have a brilliant lustre, a hardness of 5, and a sp. gr. of 3·5 (39,023). When heated by the blowpipe it gives off water, fuses on the edges, slightly swells up, and becomes opaque, at the same time giving out a green phosphorescent light. It gelatinises with acids.

It is found, though rarely, in veins in crystalline rocks, as at Matlock, Derbyshire, and other places in England; and also in irregular nests and layers in sedimentary strata, where it is generally associated with the carbonate of zinc. These layers are sometimes found of considerable thickness and extent, and have been met with at the Mendip Hills, in England; Leadhills, in Scotland; Tarnowitz, in Silesia; Bleiberg and Raibel, in Carinthia; and at numerous other localities in Europe.

DIOPTASE. ($CuO\,SiO_2+H_2O$. *Syn.* Achirite; Smaragdochalcite; Emerald Malachite; Emerald Copper.)

It crystallises in rhombohedral crystals derivable from an obtuse rhombohedron, with a terminal angle of 126° 24′, and with distinct cleavage parallel to its faces. It has a beautifully green colour, a vitreous lustre, a conchoidal uneven fracture, an index of refraction for the ordinary ray of 1·667, a hardness of 5, a sp. ht. of ·182, and a sp. gr. of 3·27 (36,452) to 3·34 (37,224). It is doubly refracting, infusible by the blowpipe, but blackens in the outer and reddens in the inner flame. With fluxes it gives the reaction of copper. It is found at Mount Altyn Tub, Berghes Karkalinsk, and Oni, in Siberia.

CHRYSOCOLLA ($CuOSiO_2+2\,H_2O$) is also a hydrated silicate of copper, but it differs from dioptase in containing a larger proportion of water. It is an amorphous compact mineral of a bluish-green colour. It breaks with a conchoidal fracture, is very brittle, and has a hardness of 2·5, and a sp. gr. of 2·3 (25,699). It is generally associated with malachite and other cupreous minerals. It

exists at Dillenberg, in Nassau; at Saska and Moldawa, in Hungary; at Canaveilles, in the Pyrenees; in the Ural and Altai Mountains; in the copper mines of Chili; in most of the copper mines of Cornwall; in Siberia, Bavaria, South Australia, Peru, and at numerous localities in the United States and in Canada. It is sometimes formed by the action of sulphate of copper on felspar, and sometimes by the alteration of malachite, as in the specimens from Chili.

DEMIDOFFITE, or *blue malachite*, as it was formerly called, forms a coating on ordinary malachite. It has a sky-blue colour, a hardness of 2, and a sp. gr. of 2·2 (24,691). It appears to be a variety of chrysocolla.

ROEPPERITE.

It is a silicate analogous to chrysolite in constitution and structure, half the protoxide of iron being replaced by the protoxides of manganese and zinc, and by magnesia. The crystals are trimetric; hardness 5·5; sp. gr. 3·95—4·01; lustre on cleavage plane vitreous to subdiamantine; colour dark green to black in the mass, but thin splinters are translucent and pale yellow, while the streak is yellow to reddish-grey. It is magnetic. Before the blowpipe it fuses with difficulty to a black slag; with the fluxes it reacts for iron, manganese, and silica; and on charcoal with soda gives a zinc coating. It readily and completely gelatinizes with acids. It has been found at Stirling Hill, Sussex Co., New Jersey, with willemite, franklinite, jeffersonite, and spinel; and at Franklin Furnace with galenite.

HUMITE.

It was formerly considered that all the crystals of humite belonged to the trimetric system, but more recent optical research shows that, while the humite crystals are rightly thus considered, there are two other varieties in which one of the axes is slightly inclined, so that they must be assigned to the monoclinic system. These two varieties are optically distinct, and hence

Dr. Cloizeaux proposes to call one *chondrodite*, and the the other *clinohumite*.

Abriachanite.

It is a hydrated silicate of ferric and ferrous oxides and magnesia, which may be noticed on account of its peculiar nature, although not accepted yet by mineralogists as an adequately defined species. It is extensively distributed near Inverness, permeating all the rocks there, such as gneiss, granite, breccia, and limestone. Professor Heddle describes it as occurring in deep-blue films coating the fissures in the rocks, as a pulpy blue clay, composed of fibres in the midst of the breccia, and as veins ramifying everywhere through the solid granite. It is hardly to be distinguished from clay in appearance, although it contains no alumina. It resembles clay in the way in which it crumbles down when placed in water. The colour is not essential to the mineral, but is probably due to a ferruginous sulphide of sodium being present, which is the same compound that is believed to be the colouring principle of ultramarine. Before the blowpipe it gives a strong sodium reaction, and with fluxes reacts for iron. It fuses with difficulty into a blotchy glass, which is strongly magnetic. Its powder is insoluble in acids.

Melanotekite.

A silicate of lead and iron, found in the massive state, and presenting cleavage in three directions. Hardness 6·5; sp. gr. 5·73; lustre metallic to resinous; colour black to blackish-grey; streak greenish grey. Fragments under the microscope are sometimes translucent, and are dichroic, being bottle-green and reddish-brown. Before the blowpipe it fuses with intumescence to a black bead; with soda on charcoal it yields a globule of lead together with a lead coating; with borax it gives an iron reaction; but on strongly heating it in the reducing flame it becomes black on cooling owing to reduced lead, and it is from this character that it has

its name. It occurs with native lead intimately mixed with magnetite and yellow garnet, at Långban, in Wermland.

Kentrolite is an allied species, being a silicate of lead and manganese.

Ganomalite.

A silicate of lead and manganese, whose composition corresponds to the formula $Pb\,\overset{\frown}{Mn}\,Si\,O_3$. It occurs in masses which are doubly refracting in a high degree, and optically biaxial, with a small angle of divergence. Hardness 4; sp. gr. 4·98; lustre greasy; colourless, or whitish and transparent. It readily fuses before the blowpipe into a clear glass, which turns black in the reducing flame owing to the reduction of the lead. On charcoal with soda it gives a lead globule and a coating of oxide of lead. It easily dissolves in nitric acid, gelatinous silica being separated. It is associated with native lead, calcite, and jacobsite, at Långban, Wermland, Sweden.

Glauconite.

A hydrated silicate of iron and potash, often containing much alumina. It can hardly be considered a well-defined species, as the composition is very variable, and it has only been met with in amorphous lumps and grains. It is largely present in many greensands and sedimentary rocks of all ages, from the Silurian onwards. It is in formation now at the bottom of the deeper oceans, where the organic matter within foraminiferal shells is replaced by it.

Hyalotekite.

A silicate of lead and baryta, which occurs in coarsely crystalline masses, which cleave easily in two directions approximately 90° one to the other, and less easily in a third direction. Hardness 5·5—6; sp. gr. 3·81; lustre vitreous to greasy; colour white to pearly grey. It is transparent in thin plates, and is optically biaxial. It fuses before the blowpipe into a clear glass, which,

when exposed to the reducing flame becomes black, owing to the reduction of lead. On charcoal, with soda in small quantity, it fuses to a clear glass, but if more soda is added, the reducing flame gives a globule of lead with a coating of oxide of lead. Insoluble in sulphuric or hydrochloric acids, but it dissolves in salt of phosphorus, leaving a skeleton of silica. It occurs at Långban, Wermland.

Ilesite is a hydrated silicate of manganese.

CHAPTER IX.

SILICATES (*continued*).

Group II.—Silicates which contain Alumina as an essential ingredient.

These groups might have been expressed in a different way. Thus, Group I. is mostly composed of the silicates of the diatomic elements; that is, of elements which, like magnesium, zinc, copper, &c., combine with oxygen in the proportion of atom for atom. Such oxides may be expressed by the general formula DO, in which D stands for any of the diatomic elements. These again may be arranged in two minor divisions, characterised by containing 1 or 2 atoms of base to 1 of silica. Thus, *willemite*, *phenakite*, and *olivine* are *dibasic*; while *enstatite* is *monobasic*. Most of the minerals described in the last chapter, such as the augites and hornblendes, are monobasic silicates, whose general formula is $DSiO_3$; in some cases the D is replaced partially or wholly by M_2, or 2 atoms of a monatomic element.

Group II. is mostly composed of silicates containing triatomic elements, of which aluminium is by far the most common. In many cases monatomic, diatomic, and triatomic elements occur together in the same mineral, so that this group presents a much greater complexity in chemical constitution than the first.

Topaz. (*Syn.* Pyrophysalite.)

This is generally considered to be a silicate of alumina combined with a silico-fluoride of aluminium. It occurs in trimetric crystals derivable from a right rhombic prism, with the vertical faces inclined at an angle of 124° 17′. The modified forms have been arranged in three groups, each characterised by a certain type of form and peculiarities of colour, &c. The three groups may be represented by (1) the topazes of Saxony, which are prisms with a rhomboidal base having a series of facets round the base, as in Fig. 48; (2) the topazes of Russia, which are prisms with a wedge-shaped summit terminating in a horizontal edge, as in Fig. 47; and (3) the topazes of Brazil, which are prisms terminated by a four-sided pyramid, as in Fig. 49. There is a distinct cleavage

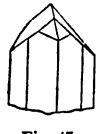

Fig. 47.

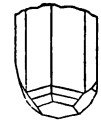

Fig. 48.

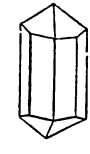

Fig. 49.

parallel to the base in all, and indistinct cleavages in two other directions. The colour varies according to the group. Thus, the Brazilian topazes are usually of a reddish yellow or rosy tint, the most common being a deep yellow approaching to orange, and the rarest a beautiful rose. This latter being highly prized, it is common to produce it artificially by slightly heating the yellow topazes. The artificially-acquired tint is not permanent. Some of the Brazilian topazes are colourless and perfectly transparent, and they have been called "drops of water" by the Portuguese. The Russian topazes are of a bluish or greenish white, and those of Saxony pale yellow. In many cases the colours are destroyed by long-continued exposure to strong sunlight, or to heat; and are probably due, not to the presence of a metallic oxide, but to that of an organic compound. The hardness is 8, the lustre vitreous, and the sp. gr. 3·5 (39,023). The topaz is elec-

trical when heated; but this property is by far the most marked in those belonging to the third type, being very slight in those of the first, and almost absent in those of the second. On the other hand, the Saxon topazes, especially the colourless varieties, are more easily rendered electrical by friction than the other kinds. The topaz is infusible by the blowpipe, but when mixed with borax it may be converted into a colourless glass. Acids have no effect on it, except sulphuric acid, which causes a disengagement of hydrofluoric acid. The crystals belonging to the first or Saxon type are found in a kind of fine-grained felspathic rock, known as *topaz rock*, at Schneckenstein, in Saxony. They are also found in stanniferous veins at Altenberg, Geyer, and Ehrenfriedersdorf, in Saxony; at Zinnwald, in Bohemia; and near St. Agnes, in Cornwall. There are many localities in the United States, and one or two, such as Muela, in Asia Minor. The crystals belonging to the second type are found at Miask, Alabaschka, and Mount Adun Tschilon, in Siberia; as also in Scotland, Ireland, and New South Wales. Those of the third type occur in the granitic rocks of Minas Geraes, at Capao da Lane, and Boña Vista, or associated with the diamond in the auriferous sands of Minas Novas and elsewhere in Brazil.

Pycnite is a variety of topaz, which contains somewhat less alumina and silica, from a quartzose rock at Altenberg; it is also found in Bohemia, Norway, Siberia, and France. It is of a pale straw colour mixed with violet.

Pyrophysalite, or *Physalite*, is a massive opaque variety of topaz, which intumesces when heated. It is found at Finbo and Broddbo, Sweden, in granite, where it is associated with fluorspar, talc, mica, albite, tantalite, and other minerals. From the latter locality a crystal weighing 80 lbs. has been obtained. Modum, in Norway, is another locality for pyrophysalite.

ANDALUSITE. (Al_2O_3. SiO_2. *Syn.* Chiastolite; Macle; Stanzaite; Micaphyllite).

This is an anhydrous silicate of alumina, which crystal-

lises in trimetric prisms, with an angle of about 91°. Some specimens are colourless, while others are rose, flesh-red, reddish-brown, or olive-green. Some of the Brazilian hyaline specimens are trichroic, and present a different colour in the direction of each axis: the three colours are hyacinth-red, yellowish-green, and olive-green. The usual colours are violet red and pearl grey. The hardness of the hyaline andalusite is 7·5, and its sp. gr. 3·16 (35,222). Its principal localities are the Forez mountains of France, near Nantes and Morlaix, in Bretagne; at Lisens, in the Tyrol; at Wunsiedel, in Bavaria; at Braunsdorf and Munzig, in Saxony; at Almeria, in Andalusia; and various places in Brazil.

Chiastolite appears to be a mixture of andalusite with some foreign matter which has been arranged symmetrically with the crystalline form of the minerals. It appears to be derived from the black schist or other dark matrix in which chiastolite always occurs. Frequently it is nothing more than dark colouring matter (probably carbonaceous) derived from the schist; for, on exposing the crystal to heat, it disappears, leaving the crystals transparent and pure: sometimes it consists of particles of the surrounding schist. The black matter assumes various forms: in some cases it has the shape of the Greek χ (Fig. 50), whence its name; more frequently it is a kind of mosaic, in which a black rhomb, having its sides parallel with the sides of the crystal, occupies the central axis, while four black lines proceed diagonally from the outer corners of the rhomb to those of the crystal; in other cases, four additional but similar rhombs occupy the four corners of the crystal; and in still other cases, there are a number of dark striæ in the clear portion, which run parallel to the inner sides of the rhombs occupying the angles. Most of the properties of chiastolite are similar to those of the hyaline andalusite, but its hardness is generally less, being sometimes as low as 5·5. It is found at many places in Europe and America.

Fig. 50.

STAUROLITE. $\overbrace{(Al_2 : Fe_2}\ O_3 . SiO_2$. *Syn.* Staurotide; Grenatite.)

This is a ferriferous andalusite, whose crystals have a remarkable tendency to assume the form of a cross, as

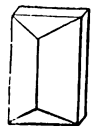

Fig. 51.

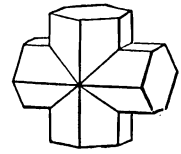

Fig. 52.

shown in Fig. 52. They belong to the trimetric system, and are derivable from a right rhombic prism, with an angle of 129° 26′ (Fig. 51). Sometimes the crystals intercross at an angle of 90°, and sometimes at an angle of 60°. Tesselated crystals, like the chiastolite variety of andalusite, have been found in the mica schist of Charlestown, in the United States. Staurolite is translucid, and of a blackish or brownish-red colour. Its lustre is vitreous, its hardness 7, and its sp. gr. 3·6 (40,140). This sp. gr. is an average, and together with the formula is, perhaps, too general. The ratio between the oxides and the silica is apparently never 1 : 1, but only approximately so. The differences actually found in the ratio are always accompanied by corresponding differences in the specific gravity, which is less in proportion as the silica increases. There are four groups of proportion known, which have distinct specific gravities as indicated below :—

Ratio between Oxides and Silica.			
Oxides.		Silica.	Sp. gr.
15	:	18	3·52
16	:	18	3·54—3·58
20	:	18	3·66—3·73
24	:	18	3·73—3·74

It is infusible by the blowpipe, and dissolves with difficulty in fused borax. It is found in the talcose schists of St. Gothard associated with kyanite and garnet; and in the argillaceous schists near Quimper and Hyères, in France; at St. Jago de Compostella, in Galicia; at

Charleston, Chesterfield, Vernon, and Lichfield, in the United States; in gneiss in Scotland.

KYANITE. (*Syn.* Rhœtizite; Disthene.)

It has the same composition as andalusite, but a totally different form. Its crystals are triclinic, and are derivable from an oblique prism in which the vertical faces are inclined at an angle of 100° 50′ towards the base. It is usually met with in long colourless or bluish lamellar crystals, which cleave readily in a direction parallel to the faces of the prism. It differs from andalusite in many of its physical properties. Thus, as regards colour, andalusite presents various shades of red, which merge gradually into green; while in kyanite the transition shades appear to be of a blue and yellow tinge. Chiastolite develops positive electricity when rubbed with sealing-wax; whereas kyanite develops positive electricity in certain crystals or on certain faces, and negative electricity on other crystals or on other faces. It was from this double electrical property that Haüy proposed to call it *disthene*. Some of the lamellæ of kyanite exhibit two colours at once, viz., a blue band between two colourless edges; sometimes they give shades of yellowish or blackish grey, the latter colour probably being due to graphite. These phenomena appear to be somewhat analogous to those presented by chiastolite. The sp. gr. of kyanite is somewhat greater than that of andalusite, being about 3·55 (39,581); that of colourless kyanite, or *Rhœtizite*, is 3·67 (40,923); and that of the blue transparent variety from the Tyrol is 3·66 (40,811). The localities for kyanite are nearly the same as those for staurolite.

SILLIMANITE has the same chemical composition as andalusite, and possesses nearly the same properties. Its crystalline form is similar, but differently modified; according to Des Cloizeaux, the primary form is a right rhomboidal prism of 111°; its optical properties are slightly different; its sp. gr. is somewhat greater, or 3·24

(36,116); and its hardness is about 7·5. *Wörthite, Monrolite, Fibrolite,* and *Bucholzite* appear to be varieties of sillimanite.

Bamlite and *xenolite* are also usually considered to be varieties of the same mineral.

In referring to the andalusite and kyanite groups of minerals, we have said nothing as to their lithological distribution. In nearly every case they are found in rocks having a similar composition to themselves. Thus, bamlite is found in gneiss; andalusite is most frequent in micaceous schist and granulite, but it also occurs in mica schist, granite, and saccharoidal limestone; chiastolite is most frequent in clay slate, and less frequent in micaceous schist; but it is also met with in fossiliferous mica schist, dark metamorphic limestones, and greyish dolomite. Kyanite is found chiefly in gneiss and mica schist; also in leptynite (a gneissose rock), eklogite, pegmatite (a granitic rock), granulite, saccharoidal limestone, dolomite, and magnesian clays; sillimanite in gneiss; and fibrolite in granite. From these facts it may be inferred that these minerals are found in the more highly crystalline rocks which originally consisted wholly or partially of silicate of alumina.

Eulytine. (Bi_2O_3. SiO_2. *Syn.* Bismuth Blende.)

From the few analyses which have been made of this rare mineral it appears to be a silicate of bismuth, which is usually mingled with a small proportion of phosphate of iron. It crystallises in hemihedral modifications belonging to the regular or monometric system, the usual form being the hemihedral dodecahedron, with dodecahedral cleavage. It also occurs in lamellar and granular masses. The colour is brown or yellow, the lustre sub-adamantine, the fracture uneven, the hardness 4·5 to 5·0, and the sp. gr. 5·9 to 6·0 (67,068). It is easily melted by the blowpipe, colouring the flame bluish green, and leaving a brown deposit on the charcoal. Hydrochloric acid dissolves it with separation of gelatinous silica. It is found

at Johanngeorgenstadt and Schneeberg, in Saxony, with *atelesite*, another mineral containing bismuth.

Garnet.

The garnets constitute a group of minerals which have for their common characters a similar chemical constitution, a similar crystalline form, and general similarity of physical properties. They form an excellent illustration of that law we have so often alluded to, by which a chemical element may be replaced by certain other chemical elements without any great change in the characters of the mineral. For instance, grossularia and the lime garnets may be represented by the formula $\overbrace{Ca : Al}.SiO_4$. The lime may be, and indeed nearly always is, replaced to a greater or less extent by magnesia, protoxide of iron, and protoxide of manganese, and when the proportion is large the garnet then belongs to the magnesian, iron, or manganese group, according as one or other of these elements prevails. Again, the alumina may be replaced by peroxide of iron or chromic acid, and these form the iron-lime and chrome garnets. This arrangement into groups facilitates description, but in nature it is rare indeed that any garnet belongs exclusively to any one group; it generally contains something which represents some other group: *pyrope*, for instance, is a mixture of lime, magnesia, iron, and chrome garnets. All the garnets crystallise in the regular or cubic system, the prevailing forms being the dodecahedron and trapezohedron; they have a vitreous or resinous lustre, and are easily fusible (except in the case of *ouwarôwite*). Their hardness varies from 6·5 to 7·5, and their sp. gr. from 3·15 (35,110) to 4·5 (50,301). They are found in almost every kind of rock, but most frequently in those which are highly hydrated, such as serpentine. The garnets found in the volcanic rocks have a peculiar vitreous lustre which is not met with in the garnets from the non-volcanic rocks.

Grossularia is a lime, or more correctly an alumina-

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lime, garnet, and is either colourless or tinged with greenish yellow in some cases, and reddish yellow in others: its sp. gr. is 3·42 (38,128). The colourless variety is found near Tellemarken, in Sweden, where it is associated with idocrase and thulite; also at Slatoust and Schischinskaja Gora, in the Ural Mountains. The greenish variety, which, from its rounded form and resemblance in colour to the gooseberry, has given rise to the name grossularia, is found in Siberia and Hungary. The reddish-yellow variety is called *essonite*. In these cases the colour is due to the presence of a little peroxide of iron. *Romanzowite* is a reddish-brown variety from Finland which contains a little of the oxides of iron and manganese.

The black garnet from Arendal resembles *melanite*, but differs in chemical composition. It is an alumina-magnesia garnet ($\widetilde{Mg : Al.}\ SiO_4$).

Spessartine is an alumina-manganese garnet ($\widetilde{Mn : Al.}\ SiO_4$) having a yellowish or reddish-brown colour. It is found at Spessart and Aschaffenburg, in Bavaria; Finbo and Broddbo, in Sweden; and Haddam, in Connecticut. *Rothoffite* is a closely-allied variety.

Almandine is an alumina-iron garnet ($\widetilde{Fe : Al.}\ SiO_4$). It is of a crimson red inclining to violet or brown. The varieties which have a clear colour and a considerable degree of transparency are called *precious* or *oriental* garnets; while the duller varieties of this group are called *common* garnets. The dominating forms of the crystals are the rhombic dodecahedron and the leucitohedron (Figs. 9 and 18, Pl. I). The crystals are sometimes very large, and usually occur in the schistose rocks, where they are frequently enveloped in a thin crust of mica, talc, or chlorite, or else in the sands and alluvial deposits derived from such rocks. The principal localities are Syriam in Pegu, Ceylon, Greenland, Brazil, Transylvania, and the Tyrol. The garnets from Elie, Fifeshire, belong to this variety. The precious garnets of Bohemia

belong to another variety, the *pyrope*. This, with one or two other of the red varieties of garnet, formed the *carbuncle* of the ancients. The *allochroite* from Drammen, in Norway, probably belongs to this group. It has a dingy yellowish or reddish colour.

Melanite is an iron-lime garnet ($\overbrace{Fe : Ca}. SiO_4$). It is of a black or brownish-black colour, and is found in the volcanic rocks at Frascati, at the foot of Vesuvius, in Lapland, and elsewhere. *Pyrenœite* is a closely-allied variety found in a dark limestone near Barèges, in the Pyrenees. *Aplome* has a greenish-brown colour, and its crystals sometimes show the faces of the cube, while the dodecahedral forms have striæ parallel to the small diagonal of the rhombs; these striæ are the signs of cubic cleavage. It is found in Siberia, Saxony, and England. *Colophonite* is a blackish-brown variety, with resinous lustre, from Norway and Sweden; and *succinite* is a similar variety, from Bonvoisin. *Topazolite* is a reddish-yellow variety from various localities in Piedmont. *Polyadelphite* is a brown variety from Franklin, in the United States.

Ouwarowite, or *Uwarowite*, is an alumina-chrome-lime garnet ($\overbrace{Al : Cr : Ca}. SiO_4$). Its colour, which is emerald green, resembles that of dioptase. It differs from the other garnets in being infusible, and in undergoing no change when exposed to the flame of the blowpipe. It is found at Bissersk, in the Ural Mountains, associated with chromite.

Pyrope is usually associated with the almandine group of garnets, but its composition and physical properties are so different that it seems better to dissociate it from that group. Its composition may be expressed by the formula $\overbrace{Al : Cr : Ca : Fe : Mn : Mg}. SiO_4$. It is rarely found in distinctly-formed crystals, but usually in rounded grains in alluvial deposits, in serpentines, or in the opal rock of Bohemia. Its colour is deep hyacinth or blood-red; its fracture conchoidal; its lustre vitreous; its hardness 7·5;

and its sp. gr. 3·6 (40,140) to 3·8 (42,376). It is difficult to fuse, and when strongly heated becomes black and opaque, but resumes its original colour and transparency when allowed to cool. It is found abundantly at Zöblitz, in Saxony; and at Meronitz, Bilin, and Podsedlitz, in Bohemia.

HUMBOLDTILITE. (*Syn.* Mellilite; Somervillite; Zurlite.)

It crystallises in forms belonging to the dimetric system. The primary form is an octahedron with a terminal angle of 134° 48′, with basal cleavage. The colour is pale yellow, the lustre vitreous, the fracture conchoidal, the hardness 5, and the sp. gr. 2·9 (32,416) to 3·1 (34,551). It fuses with difficulty into a yellowish glass, and dissolves in acids with separation of gelatinous silica. It is found in the volcanic rocks of Vesuvius, and at Capo di Bove, near Rome, associated with nepheline and breislakite. The *Gehlenite* from the Tyrol is probably a variety; it has nearly the same crystalline form, but not the same composition. Its lustre is vitreous, tending towards resinous, its hardness is 5·5, and it behaves in the same way as humboldtilite before the blowpipe, and when treated with acids. Both minerals are silicates of lime, alumina, and iron, and differ from the alumina-lime garnets in containing a much larger proportion of lime. The crystalline form is quite different from that of the garnets. Their characters are such as belong to a group of minerals, of which idocrase may be regarded as the type.

IDOCRASE. (Al_2O_3. 3 CaO. SiO_2. *Syn.* Vesuvian; Heteromerite.)

This is a silicate of alumina and lime, in which, as in the garnets, the alumina may be more or less replaced by peroxide of iron, and the lime by the protoxide of iron, magnesia, protoxide of manganese, soda, and potash. The crystals belong to the dimetric system, and are usually eight, twelve, or sixteen-sided prisms terminated by perfect or truncated pyramidal summits, having imperfect prismatic cleavage The colour is exceedingly variable, and may

be brown, violet, green, or blue. The lustre is vitreous, the hardness varies from 6 to 7, and the sp. gr. from 3·3 (36,777) to 4 (44,712). It is easily fusible, and with fluxes gives the reactions of silica and iron. It is soluble in hydrochloric acid with separation of gelatinous silica after, but not before, fusion. There are a great many varieties, and each variety is, generally speaking, characteristic of certain localities. Thus the idocrase of Vesuvius has a reddish-brown colour, and is found in the rocks thrown out by the volcano associated with spinel, zircon, garnet, meionite, nepheline, and other minerals. It is called *Vesuvian*. The idocrase of Siberia, or *Wiluite*, is of a green colour; it is found in an altered serpentine, and is associated with green garnets. *Frugardite* is a magnesian variety of an olive-green colour from Frugard, in Sweden; *Jewreinowite* is a soda-potash variety of a clear brown colour from Mantsala; *loboite* is a brownish-grey, and *gokumite* a yellowish-green, variety from Gokum, in Sweden; *cyprine*, *egerane*, and *xanthite* are other varieties. The rocks in which they occur are similar to those which form the matrix for garnets, viz., old lavas, serpentine, dolomites, and the more highly crystalline schists.

Sarcolite.

This mineral resembles the purer alumina-lime garnets in chemical composition, and might probably be represented by the same formula, but it differs from them in crystalline form and specific gravity. In these latter characters it more nearly approaches humboldtilite. It occurs in the hollows of the Vesuvian lava as transparent reddish-white dimetric octahedrons, having a sp. gr. of 2·93 (32,750). It is readily fusible into an opaque white enamel, and is soluble in hydrochloric acid, with separation of gelatinous silica.

Meionite.

Its crystals are usually four or eight-sided prisms with pyramidal summits, a terminal angle of 136° 11′, and distinct cleavage parallel to the faces of the prism.

They are generally translucent, colourless, of a vitreous lustre, and brittle. Their hardness is 5·5 to 6; and their sp. gr. 2·5 (27,945) to 2·7 (30,180). They readily melt into a colourless glass before the blowpipe, and are soluble in hydrochloric acid. They occur in blocks of limestone at Mount Somma, associated with greenish mica, wollastonite, a black garnet, augite, and hornblende. Like sarcolite, it is a silicate of alumina and lime.

SCAPOLITE (*Syn.* Wernerite; Paranthine; Ekebergite; Tetraclasite; Nuttalite.)

The crystals belong to the dimetric system, and are similar to those of méionite. They are usually columnar, and collected into groups. Some crystals are colourless, but others present various shades of grey, blue, and red, the deeper colours being most prevalent amongst the more impure varieties. The lustre is vitreous or pearly, the hardness 5·5 to 6, and the sp. gr. 2·6 to 2·7 (30,180). When heated before the blowpipe it whitens and melts into a glass. It is remarkable for its liability to decompose, and for the number of other minerals into which it may be altered: the most common pseudomorphs after scapolite consist of mica, epidote, albite, and steatite. It is found in granitic rocks, and especially in granular limestones. Amongst its numerous localities may be mentioned Tirlyh and Glenlaheen, in Donegal; Arendal, in Norway; at Moelsjo and in the province of Wermland, Sweden; at Ersby and Storgard, in Finland; and at Bolton, in Massachusetts, United States. *Atheriastite* and *Algerite* are said to be varieties. The latter contains a large proportion of water and no lime, and is essentially a hydrated silicate of alumina. *Arctizite*, *Gabbronite*, *Paralogite*, *Glaucolite*, and *Terenite* are probably scapolite in various states of alteration.

DIPYRE.

It crystallises in four or eight-sided prisms, which are apparently dimetric like those of scapolite. In lustre,

colour, behaviour before the blowpipe, and several other characters it resembles scapolite; but it has a somewhat different chemical composition, having a larger proportion of silica and alkalies, and a less proportion of lime. It is found in an unctuous argillite or argillaceous limestone at Libarens, in the Lower Pyrenees, associated with mica and chlorite; in an argillaceous limestone at Pouzac, in the Higher Pyrenees; in a saccharoidal limestone at the baths of Aulus; and in a black schist near Angoumer, in the department of the Ariège.

Couzeranite.

This mineral has nearly the same composition as dipyre, and it is found in the same localities, but is rather more abundant than that mineral. Its crystalline form has not been clearly made out, but the symmetrical octagonal prisms in which it occurs are very similar to the form of dipyre. Its colour is usually dark greyish black or blue, its lustre is waxy, its hardness 6, and its sp. gr. 2·69 (30,068). It resembles dipyre in the last two characters, as also in its behaviour before the blowpipe flame. It is said to be insoluble in acids.

Lievrite. (*Syn.* Ilvaite; Yenite.)

A silicate of iron and lime which occurs in trimetric crystals derivable from a right rhombic prism with an angle of 112° 38′. The lateral faces of the prism are generally striated in a longitudinal direction, and the striæ indicate the direction of easiest cleavage. There are also bacillar, fibrous, and compact structural varieties. The colour is brownish-black, the lustre resinous or submetallic, the fracture uneven, the hardness 5·5 to 6, and the sp. gr. 3·8 (42,376) to 4 (44,712). It is easily fused into a black magnetic globule, and is entirely decomposed by hot hydrochloric acid. Crystals are abundant and sometimes of large dimensions in various parts of the isle of Elba, where they are associated with magnetite, quartz, and garnet; and at Zschorlau, near Schneeberg, in Saxony, they are associated with epidote and augite.

Fossum and Skeen in Norway, near Andreasberg in the Harz, near Predazzo in the Tyrol, and near Bytown in Canada, are other localities where this mineral is found. *Wehrlite*, a granular compact mineral from Szurraskö, in Hungary, is sometimes regarded as a variety of lievrite. Although composed of nearly the same elements as lievrite, their proportion is not the same; this, together with its greater hardness, its more difficult fusibility, and its less perfect solubility in acids, seems to indicate that it may be a distinct species.

ZOISITE. (*Syn.* Lime Epidote; White Epidote.)

It is a silicate of alumina and lime similar to, and probably identical with, meionite in chemical composition, but with a different specific gravity. It has generally been considered as a variety of epidote, but its optical properties, direction of cleavage, and other points rather indicate that its crystals belong to quite a different system of crystallisation, viz., the triclinic. The primary form is a rhombic prism with angles of 116° 16′ and 63° 24′; the crystals are striated on their vertical faces, and are generally elongated in the direction of their principal axis. The colour is greyish or brownish, sometimes inclining to a green or rose tint. Zoisite is translucent; presents a vitreous lustre generally, but a pearly one on the plane of easiest cleavage; and has a hardness of 6·5, combined with a sp. gr. of 3·35 (37,336). When heated by the blowpipe it swells up, and is fused with difficulty into a yellow glass. Acids have little effect upon it, except after it has been calcined, when it dissolves in hydrochloric acid with separation of gelatinous silica. It occurs in the more highly crystalline rocks of the Tyrol, Carinthia, Massachusetts, and elsewhere.

ORTHITE. (*Syn.* Allanite; Cerine.)

It is closely allied to epidote, but is distinguished by containing the oxide of cerium and of the metals usually associated with it. The crystals are acicular or tabular, and belong to the monoclinic system. The colour is dark,

generally pitch-brown or brownish-black; the fracture is sub-conchoidal; the lustre is resinous and sometimes vitreous; the hardness 5·5 to 6; and the sp. gr. 3·3 (36,777) to 3·8 (42,376). It swells up before the blow-pipe flame, and fuses into a dark-coloured glass; and most of the varieties are readily soluble in hydrochloric acid with separation of gelatinous silica. The varieties are numerous; in some the proportion of iron oxides is much larger than in others; and the same variability in proportion occurs in all the other isomorphous constituents. This variability in the proportion of constituents affects the colour, specific gravity, and some other properties, but not the crystalline form. *Uranorthite* is a black variety from Miask, in the Ural; *Xanthorthite* is a yellow variety containing much water, and of low sp. gr. (2·78); *Pyrorthite* is a hydrated bituminous variety from Fahlun, in Sweden.

Bodenite is a closely-allied mineral found in orthoclase, near Marienberg, in Saxony. It occurs in prisms which appear to be rhombic, and its chemical composition differs somewhat from that of orthite.

Orthite is found in the granite of Greenland and Saxony, as also in the zircon syenite and the porphyries of Norway.

EPIDOTE. (*Syn.* Pistacite; Bucklandite; Pushkinite.)

Epidote proper embraces the aluminous ferro-calcic silicates usually called lime and iron epidotes. The crystals are monoclinic, and, according to Des Cloizeaux, are derivable from a rhombic prism with angles of 69° 56′ and 104° 15′. The colour is greenish; thus *pistacite* is a yellowish-green, *thallite* an olive-green, and other varieties present other shades. The sp. gr. is 3·3 to 3·5. The most ferruginous specimens are generally the easiest to fuse. Epidote proper is common in granite, gneiss, and syenite: it is frequently associated with magnetite and with garnet. *Bagrationite* is a mixture of orthite with bucklandite.

PIEDMONTITE is a manganesian epidote, and is of a red-

dish-brown or violet-blue colour, the sp. gr. being 3·4. It is found at St. Marcel, in Piedmont, associated with braunite and a violet tremolite. *Thulite, Withamite, Akanticon, Delphinite, Arendalite, Achmatite,* and *Tautolite* are the names of other varieties of epidote.

DICHROITE. (*Syn.* Cordierite ; Iolite ; Steinheilite ; Hard Fahlunite ; Peliom.)

In its purest state, as represented by the crystals from Krageroe, this mineral is essentially a silicate of alumina and magnesia; but both the alumina and magnesia are very liable to be replaced by varying proportions of other isomorphous substances, so as to give rise to a number of varieties. The replacing substances are peroxide of iron, lime, potash, water, and the protoxide of manganese. The crystals belong to the trimetric system, and are probably derivable from a right rhombic prism of about 120°. Like various minerals, such as cymophane, it occurs in hexagonal prisms, which have been attributed by some to the hexagonal system. Some specimens are colourless and transparent, but the majority are coloured with various shades of blue, brown, yellow, and grey. Some varieties are dichroic, others are trichroic; thus the Spanish iolites frequently appear to be of a violet blue in one direction, of a bluish-grey in another, and of a yellowish-grey in a third. The fracture is conchoidal, the lustre vitreous, the hardness 7·5, and the sp. gr. 2·7 (30,180). It is fused with difficulty into a greenish-grey glass, leaves a siliceous skeleton when fused with phosphorus salt, and is sparingly soluble in acids. The massive variety, from Orijerfvi, in Finland, is known as *Steinheilite ;* the smoky blue variety, from Bodenmais, as *peliom ;* and the transparent blue variety, from Ceylon, as the *water-sapphire.* This last is used by jewellers, and is one of the varieties which show trichroism. Dichroite is an essential ingredient in several granites and gneissose rocks, in which it takes the place of quartz, and is found in such rocks at Cabo di Gata, in Spain ; Arendal, in Nor-

way; Tunaberg, in Sweden; Haddam, in Connecticut; and Brinfield, in Massachusetts.

The alterations which dichroite undergoes without loss of crystalline form generally begin with the substitution of water for magnesia, which is followed by the substitution of potash and soda for the same substance. It depends upon circumstances what proportions of water, or potash, or soda are taken up. Thus in *praseolite, chlorophyllite, esmarkite,* and *aspasiolite,* water only is the substance taken up; while in *fahlunite, weissite, pyrargillite,* and *gigantolite,* both water and alkalies are taken up, but the water predominates. In *pinite,* and in the micas which are formed from the alteration of dichroite, water and alkalies are the new ingredients, but the alkalies predominate, especially in the case of the micas. Generally there is a far larger proportion of potash than soda. The alumina is also liable to be replaced at the same time, but the replacing substance is nearly always peroxide of iron.

Bonsdorffite is a hydrated dichroite; it occurs in greenish-brown crystals associated with unaltered dichroite in the granite of Abo, Finland. *Esmarkite* is a rather less highly hydrated variety than bonsdorffite; it is found in six or twelve-sided prisms, covered with mica scales, and dispersed through the granite of Norway. It has a greenish or brownish colour and a resinous lustre. *Chlorophyllite* contains somewhat less water than esmarkite, and a larger proportion of ferric oxide; its colour is green, and its principal localities are Unity in Maine, and Haddam in Connecticut. *Fahlunite* is also a hydrous dichroite containing a small proportion of alkalies. It occurs in greenish or reddish-brown prisms in a talcose schist near Fahlun, in Sweden. *Weissite* is the same substance, as also is the *Huronite* from Canada. *Aspasiolite* is a dichroite from the gneiss at Krageroe, in Sweden, in which water has replaced the magnesia. *Praseolite* is a hydrous dichroite associated with esmarkite at Brakke, in Norway. The *Iberite* from Montoral, in Spain, is probably the same as praseolite. *Pyrargillite* is an altered dichroite from

the granite of Helsingfors, Finland. It is of a dark black or liver-brown colour, and has a hardness of 3·5 combined with a sp. gr. of 2·5 (27,945), and a dull, earthy appearance. *Liebenerite* has been considered by some mineralogists as an altered dichroite, and by others as an altered pinite. It is found in six-sided prisms in a red porphyry on Mount Viesena, in the Tyrol. Its colour is greenish grey, its hardness 3·5, and its sp. gr. 2·1 (23,473).

Pinite is a mineral nearly allied to dichroite, and derivable from it by alteration. It occurs in six and twelve-sided prisms, having an indistinct cleavage, and a greyish-green or brown colour. The sp. gr. varies from 2·7 (30,180) to 2·8 (31,298). It differs from dichroite in containing a large proportion of peroxide of iron, potash, and water. It is found in granites, porphyries, and pegmatites in various parts of Europe and America. *Gieseckite* is a variety of pinite occurring in six-sided prisms in the porphyry of Greenland. It is considered by some mineralogists to be pseudomorphous after nepheline, but its composition and external characters are far more similar to those of pinite than of nepheline. *Killinite*, which has some resemblance to spodumene in appearance, approaches pinite in chemical composition.

Isopyre.

This is a silicate of alumina, iron, and lime, associated with tourmaline in a quartzose granite at St. Just, Cornwall. It resembles obsidian in having a conchoidal fracture, a vitreous lustre, and a black colour. It fuses before the blowpipe into a magnetic globule.

Mica.

This embraces a group of minerals whose most marked common feature is a highly laminated structure; the laminæ are brilliant, flexible, and elastic; they are generally hexagonal or rhombic in form, and have an angle closely approaching 120°. They, however, present considerable differences amongst themselves in chemical composition as well as in optical and other physical properties.

All micas are silicates of alumina and an alkali; in one group the prevailing alkali is potash, and these are known as the *potash micas;* while in another, magnesia is the prevailing alkali, and these form the group of *magnesia micas.* Coincident with this chemical difference is an optical one, viz., that while all micas are biaxial, the optic angle of the axis is small in the magnesia micas, or from 5° to 20°, and large in the *potash micas,* or from 45° to 75°. The former are sometimes called *uniaxial,* to distinguish them from the latter, which are eminently *biaxial.*

MUSCOVITE. (*Syn.* Common Mica; Phengite; Muscovy Glass.)

The crystals are rhombic or hexagonal in form and are probably derivable from a right rhombic prism with angles of 120° and 60°. They possess a remarkably easy basal cleavage, whence they are usually found in flakes or laminæ, which are generally composed of other laminæ of extreme tenuity. The colour is white, golden yellow, metallic brown, red, green, or even almost black. The lustre is pearly, the hardness 2 to 2·5, the sp. gr. 2·7 (30,180) to 3·1 (34,551), and the angle between the optic axes 45° to 75°. Muscovite readily fuses into a greyish or yellowish glass, and is not decomposed by acids. The average chemical composition is 45 per cent. of silica, 30 to 35 of alumina, and 10 to 12 of potash; the proportion of alumina is greater than in any other mica. It is exceedingly common in crystalline rocks of all ages, and is an essential ingredient in granites, gneiss, and mica schists. In these rocks it usually occurs in minute silvery scales, but occasionally it forms large plates. It is one of the most durable of minerals, and is hence frequently found in sands formed from the older rocks. *Margarodite* is apparently a variety of muscovite, as also *adamsite. Lepidomelane* is a black scaly potash mica, containing a large proportion of the ferric and ferrous oxides, and yielding a green glass when fused by the blowpipe. It is found at Paisberg, in Sweden.

Lepidolite. (*Syn.* Lithionite.)

Some of the potash micas contain lithia, and these are generally distinguished as *lithia mica.* It resembles muscovite in crystalline form and many of its physical properties. Its colour is white, yellowish, or rose-red, the last being very prevalent; its lustre pearly, its hardness 2·5 to 4, its sp. gr. 2·8 (31,298) to 3·0 (33,434), and the apparent angle between the optic axes 70° to 78°. It fuses before the blowpipe more readily than muscovite, and is decomposed by hydrochloric and sulphuric acids, but not so rapidly as the magnesian micas. The colour is due to the oxides of iron and manganese: some mineralogists, however, restrict the term *lepidolite* to the varieties which contain no iron oxide. Fluorine is present in most, probably all, varieties, and cæsium and rubidium in some. Lepidolite is most commonly met with in metalliferous veins, especially those containing tin, and is nearly always associated with other minerals which contain fluorine, such as fluorspar, topaz, tourmaline, and the emerald; it is also frequent in many kinds of granite. The more important localities where it is found are Rosena, in Moravia; Zinnwald, in Saxony; Utö, in Sweden; and Mursinsk, in the Urals; there are other localities in France and England. The *nacrite* from the schists of Coray, in Brittany, as also *odite* and *bostonite,* are generally considered to be varieties of potash mica.

Phlogopite.

The magnesia micas, of which phlogopite is one, are generally of a dark colour, and completely decomposable by sulphuric acid. They contain a large proportion of magnesia and iron oxide, and about 40 per cent. of silica. Phlogopite embraces the varieties which have the largest proportion of magnesia. It occurs in rhombic or hexagonal prisms with an angle of 120° and a marked basal cleavage, as in muscovite. They are colourless or tinged with various shades of brown and red. The angle of the optic axes varies from 5° to 20°. Phlogopite is especially common in

metamorphosed limestones and dolomites, and is very liable to alteration. It is exceedingly abundant, and attains large dimensions, in the Laurentian limestones. It is worked at North Burgess, where transparent plates are sometimes found 20 in. by 30 in. in size. It is used for various purposes, such as lamp chimneys, the fronts of lanterns, and the windows of ships of war. For this latter purpose it is especially adapted, since it is not liable to be broken by concussion as glass is. Muscovite is used for the same purposes.

Biotite.

This includes most of the ferro-magnesian micas. Its crystals are trimetric, and are generally in the form of tabular prisms with marked basal cleavage. The colour is various, but chiefly shades of green and brown; some varieties are black, and others colourless, but the commonest tints are dark green and pinchbeck-brown. The lustre is pearly, the hardness 2·5 to 3, the sp. gr. 2·7 (30,180) to 3·1 (34,551), and the angle of the optic axes less than 5°. It fuses with difficulty into a grey glass, is slightly attacked by hydrochloric acid, and completely decomposed by sulphuric acid. Biotite and phlogopite ought, perhaps, to be considered one species, since their varieties so connect the two that no line of distinction can be drawn beyond the arbitrary one that the varieties which contain a small proportion of iron oxide belong to phlogopite, and those which contain a large proportion belong to biotite. Biotite has a wide geological distribution, forming part of the older granites, gneiss, &c., as well as of the lavas from Vesuvius and other volcanoes. The varieties from modern volcanic rocks near Naples, Rome, Kaiserstuhl, and other places, are black; those from Zillerthal in the Tyrol, and Bodenmais in Bavaria, are dark green; those from Siberia and Finland are blackish green or brown; and specimens from Greenwood Furnace, near Monroe, were of a greenish tint.

Astrophyllite is a variety containing an unusual amount of ferrous oxide. It is of a pinchbeck-brown colour, and is

found at Brevigni, Norway, in star-shaped groups of crystals. *Rubellan* is probably an altered biotite It is found in reddish-brown hexagonal opaque pearly flakes, having no elasticity. It differs from the micas generally by its large proportion of lime, and is found in an amygdaloidal rock associated with augite at Schima, in Bohemia, and near Tschopau and Planitz, in Saxony. *Fuchsite* is a variety containing 6 per cent. of chromic oxide. It has a bright green colour, and is found at Schwarzenstein, in the Tyrol. A chromiferous variety, probably identical with *fuchsite*, is found at several localities in Canada, as at Bolton, Sutton, &c.

LEUCITE. (*Syn.* Amphigene; White Garnet.)

A silicate of alumina and potash, usually represented by the formula, $K_2O.Al_2O_3.4SiO_2$ = Silica 55·58, alumina 23·16, and potash 21·26. The potash is usually more or less replaced by soda. The crystals belong to the monometric system, and are nearly always of the peculiar form known as the leucitohedron, a twenty-four sided crystal with trapezoid faces. They are frequently rounded and grouped together into granular masses. They possess imperfect cleavages parallel to the faces of the cube and of the rhombododecahedron; the colour is dirty white or smoke grey; the fracture conchoidal; the lustre vitreous, but in altered specimens dull; the hardness 5·5 to 6; and the sp. gr. 2·48 (27,721) to 2·49 (27,833). It is infusible before the blowpipe, and does not yield water, in which point it differs from garnet and analcime; when heated along with a solution of cobalt it is coloured blue. When powdered it is completely soluble in hydrochloric acid.

Leucite is confined to the more modern volcanic rocks, such as the lavas of Vesuvius and Etna, and the leucite rock at Roccamonfina, in the Albanian Mountains; at Rieden, near Andernach; and at Böhmisch-Wiesenthal, in the Erzgebirge. It is unknown in the older rocks, but as it is frequently altered into kaolin, nepheline, and sanidine, which do occur in the older volcanic rocks, it is probable

that these minerals indicate the former existence of leucite in these rocks when ejected.

Berzelin of Saussure is a mineral from some of the older volcanic rocks at Lake Albano, in Italy. It occurs in grey octahedrons, having the sp. gr. and chemical composition of leucite. It is probably allied to it, but differs in yielding water when heated, and in being fusible before the blowpipe. Its crystals have also been found in the nepheline dolerite at Meiches, Oberhessen. This name has also been applied to selenide of copper (berzelianite).

NEPHELINE. (*Syn.* Sommite; Pseudosommite; Cavolinite; Beudantite.)

A silicate of alumina, soda, and potash, which crystallises in prisms belonging to the hexagonal system, and having a terminal angle of 139° 19′. It is a transparent or translucent white or yellowish mineral, the lustre of which is vitreous, the fracture conchoidal, the hardness 5·5 to 6, and the sp. gr. 2·5 (27,945) to 2·6 (29,062). The massive varieties are called elæolite, and are marked by a greasy lustre and various shades of green, grey, blue, and red. Nepheline is not easily fused into a glass before the blowpipe, but elæolite is; while both are entirely decomposed by hydrochloric acid with separation of gelatinous silica. Both are readily altered into zeolites, such as bergmannite.

Nepheline and elæolite occur in many different kinds of volcanic rocks, as, for instance, in old lava at Aich, near Andernach; at Mount Somma, where it is associated with meionite, idocrase, and hornblende; at Capo di Bove, near Rome, where it is associated with mellilite; and at Val di Noto, in Sicily; in basalt at Kaiserstuhl; and in the nepheline dolerite at Katzenbuckel, in the Odenwald; near Meiches, in Hessen; near Tichlowitz, in Bohemia; at the Lobauer Berg, in Upper Lausatia; and other localities. Elæolite is found in the zircon syenite of Brevig and Fredericksvärn, in Norway; in the miascite near Miask, associated with mica, zircon, &c.; in Finland; and various parts of the United States.

Davyne is a variety containing a little water and carbonate of lime. *Cancrinite* is also a variety containing carbonate of lime, found near Miask, in the Ural; at Marünskaja mine, in the Tunskinsk Mountains, Siberia; and at Litchfield, Maine, United States. Its sp. gr. is 2·4 (26,827), and its hardness 5 to 5·5.

Felspar.

This name is given to a group of minerals which are inferior to quartz only as a constituent of rocks. The group may be divided into two sections, of which the first will comprise those which crystallise in the monoclinic system, and which have the cleavage planes inclined towards each other at an angle of 90°; and the second such as crystallise in the triclinic system, and cleave in two directions, which intersect at an angle of less than 90°. The first section comprises one species only, viz., orthoclase, and the second albite, oligoclase, labradorite, and anorthite. The first section is called by Delesse *orthose*, and the second *anorthose*, which may be freely translated by *right-angled cleaving* felspars, and *not right-angled cleaving* felspars. Other broad points of distinction will be readily perceived on reading the following descriptions. The species are arranged according to the quantity of silica they contain, beginning with the least highly silicated. It will be noticed that as the silica increases the specific gravity diminishes, being 2·76 (30,851) in anorthite, with 43 per cent. of silica, and 2·59 (28,951) in orthoclase, with 64·8 per cent. of silica. It will also be noticed that those containing the smaller proportion of silica are soluble in acids, while those having the larger proportion are generally insoluble. There are other points of contrast, but we cannot mention them here.

Anorthite. ($\overline{Ca : Al}\ SiO_4$, or Silica = 43; Alumina = 37; Lime = 20.)

Its crystals belong to the triclinic system, and readily cleave in two directions inclined at an angle of 85° 48′.

They are nearly always grouped in twins or nuclei, as in albite. It is transparent and colourless, or translucent and greyish or reddish. Its lustre is vitreous, its fracture conchoidal, its hardness 6 to 7, and its sp. gr. 2·66 (29,733) to 2·78 (31,674). It is fusible by the blowpipe flame, although with difficulty, and it is completely soluble in strong hydrochloric acid without separation of gelatinous silica. It is generally more or less altered, the alumina being replaced by ferric oxide, and the lime by magnesia, soda, potash, and water. It has been found in the lavas of Iceland, and of the island of St. Eustache, one of the Antilles; in lavas of greater antiquity at Mount Somma; in the orbicular diorite of Corsica; and in several meteorite stones, such as those which fell at Stannern, Moravia, in 1808, and at Juvenas, near Ardèche, in 1821. It has also been found in the island of Procida, near Bogoslowik, in the Urals, and in Java.

There are many minerals which approach anorthite in composition, and which may be regarded as more or less altered varieties. *Amphodelite* is a reddish-grey variety from Tunaberg in Sweden, and Logi in Finland. *Indianite* is a white or roseate variety from a mica schist in India. *Bytownite* is an impure variety from the diorite of Yamaska Mountain, in Canada. *Polyargite* is a rose-red variety from Tunaberg. *Lindsayite* and *Lepolite* are found at Logi and Orijarfvi, in Finland. Other varieties have been recorded under the names of *Latrobite*, *Rosellan*, *Sundvikite*, and *Wilsonite*.

We may notice here the similarity in the formulæ assigned to anorthite and grossularia, especially as the two minerals differ considerably in specific gravity. This is mainly due to the alumina predominating in the lighter mineral, and lime in the heavier one. In pure anorthite the aluminium would be combined with three times as much oxygen as the lime Thus, there being two atoms of oxygen in the bases, the calcium would satisfy one-fourth, and the aluminium three-fourths, of the whole quantity of oxygen; while in grossularia the

aluminium and the calcium satisfy equal proportions. This might be represented by formulæ thus:—

Anorthite . . . . $\frac{1}{2}$ Ca Al. SiO_4.
Grossularia . . . . Ca $\frac{2}{3}$ Al. SiO_4.

LABRADORITE. ($\overbrace{2\ Ca : Al.}\ Si_3O_{10}$ or $Ca_2\ O.\ Al_2O_3.\ 3\ SiO_2$, or Silica = 53; Alumina = 30; Lime = 17. *Syn.* Labrador Felspar.)

The above formula represents that of a pure lime felspar or labradorite, but few native felspars approximate to the proportions given. The nearest is the *scolerexose* from Pargas, in Finland. The usual composition is 3 parts of lime to 1 of soda instead of lime only; that is, about 12 per cent. of lime, and about 5 of soda. The crystals, which are generally not well defined, cleave readily in two directions inclined at an angle of 86° 25′, and are commonly found in twins or aggregated clusters. The usual colour is ash or greenish grey, but it is frequently various shades of green, yellow, and red, and sometimes the smaller crystals are colourless. The lustre is vitreous, inclining to pearly or resinous, the fracture is glistening, the hardness 6, and the sp. gr. 2·6 (29,062) to 2·7 (30,180). In the labrador rock of North America and elsewhere it is characterised by its brilliant iridescent tints and striated appearance, due to the hemitropic arrangement of the crystalline plates enclosed in the mass. It is fused with greater facility than oligoclase, and when powdered is entirely decomposed by hydrochloric acid. It is particularly liable to alteration, the change effected being in most cases the replacement of alumina by ferric oxide, and of lime and soda by potash, magnesia, and water.

Labradorite enters largely into many of the rocks belonging to the *basic* group, or such as, like labradorite itself, are poor in silica and rich in the earthy oxides. It occurs in the porphyries of the Vosges and of Scotland; in the hypersthenites of Labrador, Isle of Skye, and elsewhere; in euphotide; in basalt; and in the lavas from Etna and Vesuvius.

Vosgite is an altered labradorite. The name *Saussurite* has been applied to so many different minerals, that it scarcely conveys any definite meaning; but some of the specimens so called are probably altered labradorite; while others are allied to meionite and zoisite.

HYALOPHANE. ($\widetilde{Ba : K_2}\ Al_2 Si_4 O_{12}$.)

This is a baryta-potash felspar found in the dolomite of the Binnenthal, in the Valais. It is transparent and colourless when pure; its hardness is about 7, and its sp. gr. 2·7 (30,180) to 2·8 (31,298). This specific gravity is greater than in the previous felspars, although it contains a higher proportion of silica. This exception to the rule alluded to under FELSPAR is accounted for by the presence of the heavy oxide baryta. Hyalophane crystallises in the monoclinic system, and its crystals resemble those of adularia.

OLIGOCLASE. (*Syn.* Soda Spodumene.)

This is a soda-lime felspar, which in the best crystallised specimens contains about 63 per cent. of silica, 4·2 lime, 8·4 soda, and the remainder alumina. The proportion of silica is generally below this in specimens containing a larger quantity of lime than indicated above, but it increases in proportion as there is more soda, until some varieties are scarcely distinguishable, according to composition, from certain specimens of albite. Indeed, pure oligoclase has considerable resemblance to albite, and was formerly confounded with it. Its crystals are triclinic. The directions of the two cleavages make an angle of 86° 45′. The colour is generally whitish or greyish, with shades of green and yellow; the fracture is conchoidal; the lustre is vitreous on some faces, and slightly resinous on others; the hardness 6; and the sp. gr. 2·58 (28,839) to 2·69 (30,068). It is more easily fused than albite or orthoclase, and is not decomposed by acids, except when the lime predominates over the soda. It enters as a constituent into many kinds of granite, syenite, porphyry, trachytes, and is also found in gneiss, mica

schist, diorites, leptynite, and other rocks. Its principal localities are in Sweden, Norway, Finland, the Alps, Belgium, Saxony.

Andesine is frequently considered to be a distinct species in consequence of its containing rather less silica and rather more lime than oligoclase, but according to Deville, Rose, Bischof, and other eminent chemists, this difference is not a constant one, being well marked in specimens which are evidently the most altered, and disappearing in such as have bright faces and sharp outlines, the latter being in all essential respects oligoclase. It occurs in the trachytes of the Andes and the Caucasus, and in the syenites of the Vosges. *Unionite* is in the hypersthenites of Canada, probably a highly soda-bearing variety of oligoclase. It is found in the granite of Unionville, Pennsylvania, associated with euphyllite and corundum. *Hafnefjordite* is a variety from lava near Hafnefjord, Iceland, in which lime largely preponderates over the soda.

ALBITE. $\overline{(Na : Al.}\ Si_3O_8$ or $Na_2O.\ Al_2O_3.\ 6\,SiO_2$, or Silica = 69·3; Alumina = 19·1; Soda = 11·6. *Syn.* Cleavelandite; Soda Felspar; Tetartine; Periclin.)

It differs from common felspar or orthoclase in the soda being more abundant than the potash; in its crystalline form being triclinic, not monoclinic; in its cleavages being anorthic; in the greater tendency of its crystals to form twins, which is accompanied by another character, that of striations on certain fractured surfaces; and in several other points. It is colourless and transparent, or translucent, and various shades of red, yellow, green, and grey. The lustre is vitreous generally, but pearly on the cleavage faces; the hardness 6·7, the sp. ht. ·190, and sp. gr. 2·59 (28,951) to 2·65 (29,621). Its behaviour before the blowpipe is similar to that of orthoclase, but it is somewhat more easily fused, and it gives a more distinct yellow tinge to the flame. Acids have no effect upon it. The soda is more or less replaced by potash, lime, and magnesia, and the alumina by ferric oxide. It is found in

granite, diorite, porphyry, hornblende slate, and gneiss. It is associated with magnetic iron in the quartzose slate of Wurtzburg; with chlorite and quartz in the Taunus slates at Königstein Burgberg; with calcspar in quartz dykes at Finbo and Broddbo, in Finland; with orthoclase in granite, as in Pompey's pillar; with asbestos, axinite, and chlorite in the diorite at Barèges, in the Pyrenees; with epidote and garnet at Arendal; and with eudialyte and hornblende in Greenland. It is also occasionally met with in compact limestone. It is not so common as orthoclase.

There are numerous varieties. Those of an opaque white colour are sometimes called *periclin*, or *white schorl*; the compact reddish variety is sometimes called *petrosilex*; *tetartine* embraces the specimens showing traces of cleavage in four directions. *Peristerite* is a variety from Perth, in Canada; and *hyposclerite* is an impure variety from Arendal.

ORTHOCLASE. ($\overbrace{K : Al}$. Si_3O_8 or $K_2O . Al_2O_3 6 SiO_2$, or Silica = 64·8; Alumina = 18·4; and Potash = 16·8. *Syn.* Common or Potash Felspar.)

It belongs to the monoclinic system, and its crystals are derivable from an oblique rhombic prism with an obtuse angle of 118° 52′, which cleave readily parallel to the base and to the klino-diagonal, as indicated by the dotted lines in Fig. 53. The directions of these two cleavages intersect at right angles, a character which affords a ready means of distinguishing orthoclase from the other felspars, especially albite. The modified crystals have a great variety of forms: sometimes they are short prisms, as in Fig. 54; sometimes they are elongated in the direction of the principal axis; and sometimes they are tabular. Twin crystals are frequently met with, but this feature is not so common as in albite. Occasionally four crystals are grouped into a cross, as in the adularia of St. Gothard. The purest specimens are colourless and transparent, but in those which are altered various shades of grey, red, and green

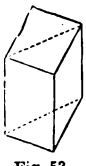

Fig. 53.

Fig. 54.

are met with. The lustre is vitreous on all the faces except those of perfect cleavage, where it is pearly. The fracture is conchoidal, the hardness 6, the sp. ht. ·183, and the sp. gr. 2·4 (26,827) to 2·6 (29,062). It is with difficulty fused by the blowpipe (on the edges only) into a semi-transparent glass; and it does not impart a strong yellow tinge to the flame, although a slight tinge is given by some varieties containing soda. Acids have no effect upon it. It occurs in granite, gneiss, syenite, felspar-porphyry, slates, and many other rocks; sometimes it is in crystals, sometimes in compact masses, sometimes in veins, and sometimes in drusy cavities. It is largely developed in the older Laurentian rocks. In the Lake Superior region it has been noticed under circumstances which imply its aqueous origin. It is found in minute reddish crystals associated with native copper. Its appearance is not that of a felspar, but of stilbite, for which it has been mistaken; however, its chemical composition and crystalline form show it to be orthoclase. It is intimately connected with the zeolitic minerals which form a larger portion of the gangue of the cupriferous veins of the district. At one part of the district orthoclase and analcime are always associated, and are frequently so situated that both must have been forming at the same time. At another place the orthoclase is associated with natrolite, and in others with quartz, epidote, and calcite. It is very liable to alteration by water acidified by carbonic or by sulphuric acid, and by water that is alkaline. The change generally consists in the loss of alkali and the assumption of water, the result being the formation of hydrated silicates of alumina, such as kaolin, pholerite, halloysite, bole, and clay; but sometimes it consists in the partial loss of both silica and alkali, the result being its conversion into other felspars, and into mica.

Its varieties are exceedingly numerous. In structure it may be either crystalline, globular, lamellar (as in the Petuntze of the Chinese), granular, or earthy. There are also several varieties in colour. Thus *Adularia* is the

transparent colourless crystals from St. Gothard and other mountainous districts. It is associated with hyaline quartz, tourmaline, rutile, anatase, asbestos, prehnite, chlorite, and other minerals. Some specimens have a peculiar bluish opalescent reflection, which has caused it to be used by jewellers, who call it *moonstone*. Fine examples of this kind have been brought from Mount St. Gothard and Ceylon. Some of the specimens of oligoclase from Siberia, having the same appearance, are also included in this term. *Valencianite* is the name given to some specimens from Valenciana mine, Mexico. *Loxoclase* is a variety with unusually distinct cleavage. Some specimens of orthoclase from the zircon syenite of Norway have iridescent tints somewhat similar to those of labradorite. *Amazon stone* is a green variety coloured by oxide of copper, and is found in the Ural Mountains. *Aventurine felspar* is a green variety which has embedded in it minute specks of specular iron, which reflect a copperyred or golden-yellow light. *Sunstone* is a similar variety. Some specimens of oligoclase from the neighbourhood of Archangel have similar internal reflecting points.

Common orthoclase is the opaque, or translucent, white, greenish, or reddish variety which enters so largely into granites, syenites, &c. Its localities are too numerous to mention, but Baveno in Piedmont, Chudleigh in Devonshire, Arendal in Norway, Elnbogen in Bohemia, Alabaschka in the Ural Mountains, Rossie in the State of New York, the Mourne Mountains in Ireland, afford fine crystals. *Sanidine*, or *glassy felspar*, is usually found in volcanic rocks, such as trachyte and basalt. Some specimens of it from Vesuvius are called *Rhyacolite* and *Icespar*. *Petrosilex* is a compact felspar largely mixed with quartz and other minerals. It forms the base of leptynite and many porphyries. The term is also often applied to certain specimens of albite and oligoclase. *Baulite*, or *Krablite*, also seems to be an orthoclase largely mixed with quartz. *Adinole* is a reddish translucent petrosilex from Sahlberg, in Sweden. *Necronite* is a variety which emits a fetid odour when struck. *Ches-*

ıerlite is from Chester County, Pennsylvania. *Murchisonite* is a flesh-red variety from Heavitree, near Exeter. *Leelite*, or *Helleflinta*, is a similar variety with waxy lustre from Gryphyttan, in Sweden. *Variolite* is a dark green variety from the river Drac, in France. *Microclin* is from Arendal. *Perthite* is from Perth, in Upper Canada. *Weissigite* is a rose-red or flesh-red variety which is found in the form of laumontite in the Kilpatrick Hills of Scotland, and elsewhere. Its sp. gr. is 2·5.

There is a group of amorphous minerals which enter more or less largely into the ejections from volcanoes, and which, from their resemblance in chemical composition to one or other of the felspars, may be noticed here.

Obsidian (*Syn.* Volcanic Glass; Marekanite) is a substance resembling in external appearance a black glass. It breaks with a conchoidal fracture of large curvature, and yields sharp cutting edges. In the mass its colour is generally very dark, but in thin layers the colour appears blackish-green, greyish, or brown, and is accompanied by a certain degree of translucency. As it is derived from the fusion of various kinds of rocks, its composition is inconstant, and its characters are also variable. The proportion of silica ranges between 60 to 80, and that of alumina, which is nearly always the next most abundant ingredient, between 9 and 19. The hardness is about 6 or 7, the lustre vitreous, and the sp. gr. 2·2 (24,491) to 2·5 (27,945). When heated by the blowpipe it swells, froths up, and ultimately yields a white enamel. The Mexicans formerly used it for knives, in the same way as flint was used by the older inhabitants of Western Europe. *Pele's Hair* is a capillary variety from Hawaii.

Pitchstone (*Syn.* Retinite) has a conchoidal fracture and a resinous lustre. The colour consists of various shades of grey, green, yellow, and red; the specific gravity scarcely differs from that of obsidian. When calcined it yields a little ammoniacal vapour, and, with stronger heat, yields a grey enamel. Its principal localities are Cantal, in France; Trebischthal, Planitz, and other places in Saxony; Santa Natolia, in Sardinia; in Hungary,

Iceland, Siberia, Mexico, and Peru; and at various localities in Scotland and Ireland.

Pearlstone (*Syn.* Perlite) differs but little chemically from some obsidians; some varieties, however, are fusible, while others are infusible, by the blowpipe, a difference due to certain secondary ingredients prevailing in some and not in other specimens. The pearlstones are built up of a number of small spheres, which have occasionally a pearly appearance and a concentric structure; but in some instances their structure is radiated. The latter variety of pearlstone is sometimes called *sphærulite.*

Pumice is like obsidian in composition, but usually contains a larger proportion of soda and potash. Its structure is widely different, being remarkably porous and spongy. It is hard, easily reduced to powder, and much employed for polishing marble, glass, metal, wood, and other materials. It abounds in certain volcanic districts, as at Vesuvius, Herculaneum, Pompeii, Lipari Islands, Teneriffe, Hungary, Auvergne, and elsewhere. *Graphic granite* and *leopardite* are of a felspathic nature, but are rocks rather than minerals; a remark which equally applies to obsidian, pitchstone, pearlstone, and pumice.

Spodumene. (*Syn.* Triphane; Killinite.)

This and the succeeding mineral are arranged close to the felspars by some mineralogists; but there are several points which seem to connect them with the augites, such as crystalline form and chemical constitution. Thus spodumene may be expressed by the general formula $\overbrace{(Li : Na)}_2 Al_2 Si_4 O_{12}$, which, when divided by 4, and on the supposition that lithia is the only alkali present, would become $\overbrace{Li : Al}\ SiO_3$, which corresponds to the constitution of the augites, as also of hyalophane amongst the felspars. The theoretical percentage composition, according to the above formulæ, excluding the soda, would be silica 64·3, alumina 27·7, and lithia 8, which approximates, closely to the analyses of the purer specimens. These, however, are never quite free from alteration, but contain

potash, soda, and magnesia, in place of some of the lithia. The crystals are oblique rhombic prisms with angles of 87° and 93°, and with distinct cleavages parallel to the prismatic faces and to the short diagonal. These angles, it will be noticed, are the same as those met with in the augites. The crystals are rare, the usual mode of occurrence being in laminar masses. These plates have an apple-green or greenish-grey colour; a pearly lustre on the cleavage faces, and a vitreous one on the others; an uneven fracture; a hardness of 6·5 to 7; and a sp. gr. of 3·2 (35,669). When heated before the blowpipe it imparts a slight reddish tint to the flame, which is brightest in the specimens containing the least soda. When fused with carbonate of soda on platinum it leaves a dark yellow stain. Acids have no effect upon it.

It is found in gneiss associated with petalite at Utoe, in Sweden; in granite at Killiney, near Dublin; and at Peterhead, in Scotland; in mica schist at Goshen, in Massachusetts, associated with tourmaline; at Chester and Norwich, in the same State. The crystals from the last-mentioned locality are remarkable for their size and their resemblance in form to diopside. Some crystals from Chesterfield, Mass., are thirty-five inches long.

PETALITE. (*Syn.* Castor.)

The formulæ proposed to represent this mineral are exceedingly various, and the simplest we have seen in books is perhaps $3\,(M_2O.2\,SiO_2).4\,(Al_2O_3.6\,SiO_2)$; but it is more simply expressed by the formula $Li_2O.\,Al_2O_3\,8\,SiO_2$, which is analogous to the formula of a highly silicated felspar. And this may be reduced to the still simpler expression

$\overline{Li : Al}.\,Si_4O_{10}$, which would give the percentage composition of silica, 77·6; alumina, 16·7; and 5·5 lithia. The lithia is always partially replaced by soda, or lime, or magnesia. Its crystalline structure is unknown, for as yet it has been found only in laminar and amorphous masses, which afford cleavages in three directions, the angles between which are 142°, 117°, and 101°. Those

forming the first-mentioned angle are the most distinct. It is probable that the crystals when found will belong to the monoclinic system. The colour is grey in some specimens, and greenish or rosy in others; the lustre is pearly on the cleavage faces, but on the others vitreous; the fracture is conchoidal; the hardness 6·5 to 7; and the sp. gr. 2·42. When heated before the blowpipe it melts readily on the edges, and gives a reddish tinge to the flame, which, however, soon passes off. Acids have no effect upon it.

It was originally found at Utoe, in Sweden, associated with spodumene, lepidolite, tourmaline, and other lithia-bearing minerals. In the island of Elba it occurs as colourless transparent vitreous masses in granite, associated with a variety of sanidine, which Breithaupt called *Pollux;* and hence this variety of petalite has been called *Castor.* Petalite has also been found at York, on the shores of Lake Ontario, as well as at Bolton and Sterling, in Massachusetts.

Beryl.

A silicate of alumina and glucina, which, when pure, is probably composed of 67·5 per cent. of silica, 18·7 of alumina, and 13·8 of glucina. It crystallises in modified regular six-sided prisms belonging to the hexagonal system, and generally having vertical striations on the prismatic faces.

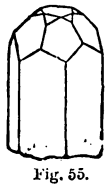

Fig. 55.

The end of one of these crystals is shown in Fig. 55. The cleavage is basal, and sometimes prismatic. Some varieties are translucent and colourless, while others present various shades of yellow, bluish green, and bright green. The lustre is vitreous, the fracture conchoidal, the hardness 7·5 to 8, and the sp. gr. 2·67 (29,845) to 2·76 (30,851). With the blowpipe flame it is only fusible on the edges, but the heat renders it opaque, and in some specimens drives off the colour. Acids have no effect upon it.

Most specimens of beryl contain small quantities of chromic or ferric oxide, and it is to these substances that

their colour has been attributed. According to M. Lewy, the colour is rather to be attributed, partly or wholly, to the presence of an organic matter, which appears to be some hydrocarbon. He found that the colour of the emerald of New Granada was deepest in those specimens which contained the largest quantity of this organic matter, even in cases where the proportion of chromic oxide was exceedingly small. He also refers to the decoloration of the green emeralds, which appears to be inexplicable, if the colour is attributed to the chromic oxide. There are several varieties of crystalline form, the most interesting of which is the hexagonal prism without any modification. Specimens of it occur at Chanteloupe, in France; others having a length of from four to five feet, and a weight of from two thousand to three thousand pounds, near Crofton, in the United States; and others in Siberia and Columbia. There are also varieties of colour: the more important of these are the *emerald*, the noble beryl or *aquamarine*, and the *common* beryl.

The emerald is found in various granitic and schistose rocks, and in veins traversing them. The emeralds of the ancients were probably obtained from the old mines at Mount Zabarah in Upper Egypt, where they are dispersed through mica schist. The best modern emeralds are chiefly obtained from New Granada, and are superior to those of the ancients, both as regards colour and translucency. The principal mines are situated at Muzo, near Santa Fé de Bogota. According to Lewy, they form horizontal bands in a fossiliferous bituminous limestone which rests upon black schists, and which, from the organic remains contained in it, is assigned to the lower cretaceous formation. The emeralds are associated with calcspar, hyaline quartz, iron pyrites, and occasionally parisite. The emerald is also found in a black mica schist at Katharinenberg, in Siberia; in a similar rock in the Heubach valley, Salzburg; in the granite of Nertschinsk, in Siberia, and of the Mourne Mountains, in Ireland. It has been produced artificially by Daubree. The aquamarine has a greenish-blue colour, and is found in granitic

rocks at Cangarjum, in India; in Brazil, in Silesia, in France, in Wicklow and Dublin counties, and at Kinloch, Runnock, and Cairngorm, in Aberdeenshire: in many of these localities it is associated with the topaz. The common beryl is of a honey-yellow, yellowish-white, or brownish-grey colour, and is widely distributed; the localities being situated in Finland, Norway, Sweden, Saxony, Bohemia, Bavaria, France, Ireland, and United States.

Davidsonite is an impure variety from a granite vein near Tory, and from the granite of Rubieslaw: both localities are in Aberdeenshire.

EUCLASE. ($\overbrace{Gl : Al}$. $SiO_4 + H_2O$. *Syn.* Prismatic Emerald.)

This, like the preceding mineral, is a silicate of alumina and glucina, but differs from it in being hydrated. It appears to have the chemical constitution of a garnet, but it differs from garnets in its crystalline form, which is a modified monoclinic prism with angles of 115° and 107° 37′. The prisms are always short, with the faces marked with vertical striæ, and with a remarkably easy cleavage. Some specimens are transparent and colourless, others translucent and yellowish, greenish, or bluish. The lustre is vitreous, the fracture conchoidal, the hardness 7·5, and the sp. gr. 3·1 (34,551). With the blowpipe thin splinters are with difficulty fused into a white enamel; it does not melt when heated with borax or phosphorus salt, and it is insoluble in acids.

Euclase was at first found only in the mica schists of Brazil, associated with hyaline quartz and topaz, and was for a time an exceedingly rare mineral. It has become somewhat less scarce since its discovery at Trumbull, Connecticut, associated with topaz, fluorspar, and mica; in the Ural Mountains, associated with kyanite, topaz, corundum; and since its artificial formation by Daubree.

KAOLIN. (*Syn.* Porcelain Earth.)

This can hardly be considered a distinct mineral species, inasmuch as it is the product of decomposition of

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felspar and other minerals, and never occurs in any crystalline form of its own. Moreover, its composition varies somewhat according to the source from which it has been derived. In many cases it answers to the formula $Al_2O_3 . SiO_2 + 2H_2O$. In all cases it is a hydrated silicate of alumina, and its usual source is felspar. It is a friable, soft substance of a white, yellow, or flesh-red colour, and capable of resisting the highest heat of a porcelain furnace. It usually contains more or less silica in an uncombined state. The sp. gr. is 2·2 (24,591). The kaolin of Cornwall is derived from the decomposition of granite; that of St. Yrieux from the decomposition of gneiss; and that of Passau from the decomposition of granulite. Kaolin is almost entirely from the older felspathic rocks, while clays, which are impure hydrated silicates of alumina, are generally derived from younger rocks.

Halloysite. (*Syn.* Halloylite; Halloyte.)

A hydrated silicate of alumina, which resembles ordinary clay in many points, but differs from it in containing rather more water when simply air-dried. It occurs in white or bluish-white amorphous masses, which break with a conchoidal waxy fracture, and when purest is translucent at the edges. It adheres to the tongue, does not fall to pieces when placed in water, and is decomposed by sulphuric acid, with separation of gelatinous silica. The heat of the blowpipe renders it hard and opaque white. It is found in diluvial clay at Ecogne, in the department of Ardennes; in tertiary strata at Champagne and Milo; in some of the metalliferous lodes containing iron, manganese, lead, and zinc, near Liège and Namur, in Belgium; and in various localities in Central France. It is probably derived from the decomposition of alkaline silicates of alumina, most frequently a felspar. The halloysites differ somewhat in their composition, and cannot be represented by any single formula; but those from Belgium and Central France so far resemble one another that they may be represented by $2 (Al_2O_3 . 2 SiO_2) + 9 H_2O$

when air-dried; a formula which points to their origin from potash felspar, *i.e.* orthoclase. The mode of derivation is by the action of carbonated waters, the carbonic acid of which combines with the potash to form soluble carbonate of potash; at the same time the silica being released, remains uncombined, while the place of the potash is taken by water. If the action is slow, the silica is carried off in solution, but if fast it remains separated as quartz. This explanation will apply to many other bodies which more or less resemble clay.

LITHOMARGE, or *Steinmark*, is a clay-like substance of a white, yellow, red, or bluish colour. It has a greasy feel, a conchoidal fracture, a shiny streak, a hardness of 2 to 2·5, and a sp. gr. of 2·5. It adheres to the tongue, hardens when heated, and sometimes becomes phosphorescent. It is found in veins traversing granite, associated with quartz and topaz. *Teratolite* is a variety of lithomarge.

DELANOVITE is by some mineralogists called a variety of halloysite, and by others a variety of bole. It is a reddish amorphous substance, which has an earthy or splintery fracture, a waxy lustre, and a hardness of about 1. It adheres to the tongue, is slightly plastic with water, is infusible, and is decomposed by sulphuric acid. It is found at Michac, in France. It contains 50·5 per cent. of silica. *Montmorillonite* and *Severite* appear to be identical with *Delanovite:* the only difference is the colour, which in the first is reddish, due probably to the oxide of iron present; in the second absent; and in the last is reddish, due to protoxide of manganese. All three appear to be derivable from orthoclase by reduction of silica and substitution of water for potash.

Lenzinite is a hydrated silicate of alumina, of which there are said to be two varieties, one opaline, with a sp. gr. of 2·1 (23,473), and the other argillaceous, sp. gr. 1·8 (20,120). It is found at the Kall, in the Eifel; and at La Vilate, near Chanteloupe, in France. The specimens from the former locality are white; those from the latter

a clear brown. It is reddened, but not fused, by the blowpipe, and is decomposed by sulphuric acid.

Nertschinskite, Melopsite, Malthacite, Glagerite, Orawitzite, Glossecollite, are the names for minerals which are usually regarded as varieties of halloysite.

Allophane is a hydrated silicate of alumina which has an opaline appearance, a conchoidal fracture, a variable colour, being sometimes white, and at other times green, blue, brown, or black. It is infusible, but loses its colour when heated. It dissolves readily in dilute acids, and deposits gelatinous silica when treated with concentrated acids. It occurs in the chalk-pits at Charlton, near Woolwich; in the chalk at Chislehurst near Bromley, and at Beauvais in France; at Richmond, Massachusetts; at the Bristol copper mine, Connecticut, United States; at Northampton and elsewhere. It usually occurs as a lining to the small cavities in marl or chalk.

Schrötterite is a hydrated silicate of alumina, with about 42 per cent. of water, and 10·5 per cent. of silica. It is amorphous; the colour is greenish, yellowish, or brownish; the lustre vitreous; the fracture conchoidal; the hardness 3 to 3·5, and the sp. gr. 1·95 to 2·05. It is infusible by the blowpipe, but when heated becomes first opaque and white, then lavender-blue, and lastly again opaque and white. It is soluble in hydrochloric acid with separation of gelatinous silica. It is found near Freienstein, in Styria; and in a dark-coloured bituminous slate near the falls of Little River, in Alabama, United States.

Dillnite is a hydrated silicate of alumina, with 20 per cent. of water and 23·5 per cent. of silica. It is white, earthy, and opaque. It adheres to the tongue, has a hardness of 1·8 to 2, and a sp. gr. of 2·57 (28,727). It forms the matrix in which diaspore is found at Dillu, near Schemnitz.

Kollyrite is a hydrated silicate of alumina, with 40 per cent. of water and 15 per cent. of silica. It is a soft white earthy substance. It adheres to the tongue, has a hardness of from 1 to 2, and a sp. gr. of about 2 (22,356). When placed in water it becomes transparent, and

crumbles down. It is soluble in acids with separation of gelatinous silica. It is found in the lead mines at Esquerra, in the Pyrenees; in veins traversing porphyry near Schemnitz, in Hungary; and in a variegated sandstone near Wissenfels, in Saxony.

Scarbroite is a hydrated silicate of alumina, with 47 per cent. of water and 10·5 of silica, which is very similar to Schrötterite. Although similar to it in chemical composition, the physical properties differ in several points. It is of a pure white colour, devoid of lustre, breaks with a conchoidal fracture, and has a hardness of 2, and a sp. gr. of 1·48 (16,543). When immersed in water it neither becomes translucent nor crumbles down. It is found near Scarborough, Yorkshire, in a calcareous rock.

Bole is a hydrated silicate of alumina and iron, of a somewhat variable composition, but generally containing about 42 per cent. of silica and 24 per cent. of water. It contains also a large amount of ferric oxide, which gives it its yellow-red or brownish-black colour. It is soft and greasy, translucent or opaque, adheres to the tongue, and falls to pieces with a crackling noise when immersed in water. The hardness is 1·5, and the sp. gr. 1·4 (15,649) to 2 (22,356). It is fused with facility into a greenish enamel. It closely resembles halloysite in its chemical composition, the principal difference being the presence of ferric oxide in bole. The differences in physical properties also appear to be mainly due to the presence of this oxide. Halloysite does not fall to pieces when placed in water, but it absorbs the water with evolution of air bubbles; the same action occurs in bole, and is followed by its crumbling down. The difference appears to be rather of degree than of kind. The easier fusibility of bole is to be attributed to the ferric oxide. Bole is found in clay slate or basalt at Säsebuhl, near Göttingen; at Stolpen, in Saxony; at the Brechte Berg, in Silesia; at the Giant's Causeway, in Ireland; and at other localities. The Irish bole is sometimes called *erinite*, a name also used for arseniate of copper.

Plinthite is a hydrated silicate of alumina and iron,

with about 31 per cent. of silica, 19·6 of water, and 26 of the protoxide of iron. It is of an opaque brick-red colour; the lustre is dull, the fracture flat conchoidal, the hardness 2·75, and the sp. gr. 2·35 (26,258). It is blackened by the blowpipe, but not fused; and is found at Down Hill, Antrim, and in a reddish rock at Little Deer Park, near Glenaur.

Anauxite is a hydrated silicate of alumina and magnesia, with about 55 per cent. of silica and 11·5 per cent. of water, from Bilin, in Bohemia. It is of a greenish-white colour, and has a pearly lustre, a hardness of from 2 to 3, and a sp. gr. of 2·26 (25,262).

Rocksoap is very similar to halloysite, but has a dark brown colour, and falls to pieces when immersed in water.

Cimolite is a hydrated silicate of alumina found abundantly in the island of Argentiera, called Cimolos by the ancients. It is of a light greyish-white colour, and breaks with an uneven fracture. Its lustre is greasy, and its sp. gr. is 2·1 (23,473) to 2·3 (25,699). When placed in water it breaks down into thin flakes. It contains about 63 per cent. of silica, and 12 per cent. of water. It is found at Alexandrowski, in Russia, and pseudomorphous after augite in basalt at Bilin, Bohemia. *Pelikanite* is a variety from decomposed granite at Kiev, in Russia. *Hunterite* is probably another variety from coarse granite near Nágpur, in Central India. *Paligorskite* is probably allied to cimolite.

Pyrophyllite is a hydrated silicate of alumina, containing about 65 per cent. of silica. Its formula is $2\ Al_2O_3.\ 9\ SiO_2.\ 3\ H_2O$. It occurs in foliated talc-like masses of a white, green, or yellow colour, and with a pearly lustre. It is flexible in thin laminæ; its hardness is 1; and its sp. gr. 2·7 to 2·8. When treated with the blowpipe it swells up into leaf-shaped masses, which have a bulk twenty times what they originally had. It is partially soluble in sulphuric acid. It is associated with kyanite, rutile, and quartz in a hæmatitic rock at Graves' Mount, in Georgia; it is also found at Cottonstone Mountain, in South Carolina; at Westana, in Sweden; at Spa, in Belgium; and

near Pischminsk, in the Ural Mountains. Some of the agalmatolites closely resemble pyrophyllite in chemical composition.

Wolchonskoite is a greenish earth which has the aspect and constitution of clay. It is a hydrated silicate of iron and chrome, and is composed of about 37 per cent. silica, 22 per cent. water, and the remainder mostly ferric and chromic oxides. It has a flat conchoidal fracture, a hardness of 2·5, and a sp. gr. of 2·2 to 2·3. It adheres slightly to the tongue, and dissolves in strong hydrochloric acid with separation of gelatinous silica. It is found at Okhansk, in the government of Perm, Russia. *Chrome ochre* is a name sometimes given to native chromic oxide, and sometimes to the clay which contains it. This clay has a green colour and a dull earthy appearance, and a sp. gr. of 2·7. The chromic oxide is generally only the colouring principle, as in the specimens from Creuzot in France, Mortenberg in Sweden, Silesia, and Piedmont; but at Unst, one of the Shetlands, the incrustation on the chromic iron ore is mainly composed of chromic oxide, and like the chromiferous clays, is called chrome ochre.

Uranophane is a hydrated silicate of uranium, composed of about 16 per cent. of silica, 14 per cent. of water, and 50 per cent. of oxide of uranium; the remainder consists of alumina, lime, magnesia, and other substances. It is a compact, apparently amorphous, greenish mass, but is really made up of a number of microscopic acicular or hexagonal prismatic crystals. The hardness is about 3, and the sp. gr. in pure specimens 2·78 (31,074).

NONTRONITE. (Fe_2O_3. 3 SiO_2 + 5 H_2O, or Peroxide of Iron = 37·3; Silica = 41·8; and Water = 20·9.)

There are a number of minerals which are either hydrated persilicates of iron or hydrated protosilicates of the same metal. They are generally more or less chemically and mechanically impure, so that it is exceedingly difficult to ascertain what properties and what proportion of constituents are to be assigned to any definite mineral species. A nontronite from Andreasberg analysed by

Biewend is a pure mineral having a composition answering to the formula given above. In other specimens the alumina, ferric oxide, and water have been partially replaced by alumina and magnesia. It has an opaline earthy appearance, a translucent or opaque straw-yellow or siskin-green colour, a dull lustre, a splintery fracture. It is soft to the touch, and when immersed in water becomes transparent and gives off air bubbles. The hardness is 2 or 3, and its sp. gr. 2 to 2·3. It is infusible by the blowpipe, but when heated with it, it decrepitates, turns first brown, then black, and becomes magnetic. It gelatinises in acids. It is found in reniform masses at the manganese mines of St. Pardoux, near Nontron, in France; also at Montmors, near Autun; and at Andreasberg, in the Harz.

Gramenite is a hydrated persilicate of iron, in which a large proportion of the ferric oxide has been replaced by alumina, protoxide of iron, &c. Disregarding these substitution substances, the mineral appears to answer to the formula $Fe_2O_3 . 3\,SiO_2 + 6\,H_2O$. Its colour is grass-green, and from this it gets its name. This colour is probably due to the small quantity of protoxide of iron which it contains. Its lustre is greasy, its hardness 1, and its sp. gr. when dried 1·87. It turns brown when slightly heated. It is decomposed by acids. It is found at Menzenberg, as also at Smallacombe, and is formed by the decomposition of a felspathic rock. It presents a certain similarity in percentage composition to halloysite, which may be due to its having originated in a somewhat similar way. A six-atom silica potash felspar, when deprived of four atoms of its silica, becomes—potash, 26 per cent.; alumina, 34·2 per cent.; and silica, 39·8 per cent. Halloysite, which is probably such a felspar with water in the place of potash, has the composition—water, 26·5; alumina, 34; and silica, 39·5 per cent. Gramenite may be compared to an halloysite having ferric oxide in the place of alumina. According to the formula above given, it would consist of water, 24; ferric oxide, 39; and silica, 40 per cent.

Chloropal is a hydrated persilicate of iron of variable composition according to the analyses published. There are said to be two varieties, one of which breaks with a conchoidal fracture, while the other is earthy and friable. Some of the specimens of the former appear to be nontronites mixed with a little opal. They have a pistachio-green colour, a sp. gr. of 2·15, and a hardness of 4·5. The peculiar green tint would seem to imply that some of the oxide is ferrous oxide. It turns black when heated by the blowpipe, and is soluble in hydrochloric acid with separation of silica. It is found in Hungary and near Göttingen.

Pinguite resembles chloropal, but differs in containing ferrous oxide, and rather less silica. Its composition may probably be represented by $\frac{2}{3}\,Fe_2O_3 . \frac{1}{3}\,FeO . 2\,SiO_2 + 5\,H_2O$. It is found in masses, having an oil-green colour, a resinous lustre, a greasy feel, a hardness of 1, and a sp. gr. of 2·3 (25,699). In its general behaviour towards acids and the blowpipe flame it resembles chloropal. It occurs in veins of heavyspar traversing gneiss at Wolkenstein, in Saxony; at Tannhof, near Zwickau; and at Suhl, in the Thuringerwald.

Anthosiderite is a hydrated persilicate of iron found at Minas Geraes, in Brazil, associated with magnetite. Its colour is yellowish-brown, and it is fusible by the blowpipe into a black magnetic slag.

Carpholite.

This is a hydrated silicate of alumina, manganese, and iron, having a straw-yellow colour, a silky or pearly lustre, a hardness of 5, and a sp. gr. of 2·9 (32,416). The crystals occur in tufts, arranged in radiating or stellar groups, or in rhombic prisms with angles of 111° 27′ and 68° 33′. These angles approach those found in the epidote group. Carpholite boils up when heated with the blowpipe flame, and fuses into a brownish glass. It is found in granite in the tin mines of Schlaggenwald, in Bohemia.

PREHNITE. (*Syn.* Koupholite; Edelite; Chiltonite.)

It crystallises in forms derivable from a right rhombic prism of 99° 56′; the crystals are generally flattened or tabular, but are rare in an isolated state, usually occurring in aggregated clumps having a rounded lenticular or bivalved-shell form. Prehnite also occurs in nodules having a more or less fibrous structure. The colour is in most cases greenish, the powder, however, being white; the lustre is vitreous, and slightly pearly on the basal face; the hardness is 6 or 7; and the sp. gr. 2·8 (31,298) to 3 (34,434). It is pyroelectrical, gives off water when heated, and melts before the blowpipe into a white or yellowish blebby glass. Hydrochloric acid has little effect upon it before calcination, but readily dissolves it, with separation of gelatinous silica, after calcination. It is a hydrated silicate of alumina and lime, and may be represented by the formula $Al_2Ca_2\ Si_3O_{11} + aq.$, or as Rammelsberg expresses it $(2\ CaO\ SiO_2 + Al_2O_3.\ SiO_2) + aq.$ It is found in numerous localities where such rocks as granite, diorite, euphotide, syenite, and mica schist occur, and the minerals most frequently associated with it are quartz, adularia, albite, epidote, and datholite.

NATROLITE. (*Syn.* Needle Zeolite; Mesotype.)

It is a hydrated silicate of alumina and soda whose primary form is a rhombic prism of 91°. The crystals are frequently acicular, and arranged in fibrous divergent tufts, as indicated in Fig. 56. The cleavage is perfect parallel to the vertical faces of the primary form; the fracture conchoidal; the lustre vitreous; the colour white, greyish, reddish, or greenish; the hardness 5 to 5·5; and the sp. gr. 2·17 (24,256) to 2·25 (25,150). When fresh from its matrix its water of

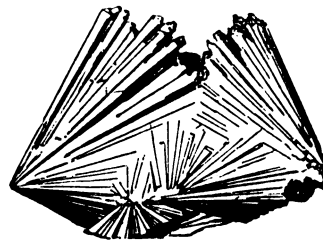

Fig 56.

combination is given off at about 460° F., and it becomes milky and opaque. Specimens thus treated regain their water on exposure to the air, but not their transparency; and this water is driven off at a heat somewhat less than 400° F. Before the blowpipe natrolite melts into a greenish or colourless glass, and readily gelatinises with acids.

It is usually found in nodular masses, having a fibrous radiating structure, in basalts, phonolite, dolerite, and similar rocks, associated with other zeolites. It is rare in the more highly crystalline rocks, but has been met with in the zircon syenite. It occurs in many places in the Auvergne district, the Alps, Hungary, Transylvania, Scotland, Ireland, &c. There are several varieties.

SCOLECITE. (*Syn.* Mesolite; Needle Stone.)

This was at one time confounded with natrolite, which is a soda zeolite, whereas scolecite is a lime zeolite, having its own distinctive characters. Its primary form is an oblique rhombic prism of 91° 22′. The crystals are always in twins, and two of their contiguous faces are characterised by oblique striæ. The cleavage is the same as in natrolite, as also the fracture and lustre. The crystals are colourless, have a hardness of 5 to 5·5, a sp. gr. of 2·2, and are pyroelectric. They boil up, twist and curl like a worm, fuse readily before the blowpipe, and yield gelatinous silica when treated with hydrochloric acid.

The well-defined transparent crystals are rare; the best occur at Bernfjord in Iceland; Niederkirchen in Bavaria, Poonah in India, Cachapual in Chili, as also the islands of Mull, Staffa, Skye, and Faroe are amongst its other localities.

Thomsonite is a lime-soda zeolite with characters differing little from those of the two preceding minerals.

STILBITE. (*Syn.* Desmin; Radiated Stilbite.)

Its primary form is a right rhombic prism with an

angle of 94° 16′. The cleavage is distinct parallel to the larger face shown in Fig. 57, which face is always striated. The crystals are semi-transparent, sometimes colourless, and sometimes tinged of a light yellow or red tint, but the powder is white. The fracture is uneven; the lustre vitreous on most of the faces, but pearly on that of easiest cleavage; the hardness 3·5 to 4; and the sp. gr. 2·1 (23,473) to 2·2 (24,591). It resembles selenite in its flat tabular form, in its translucency, and in its readiness of cleavage; the two may be easily distinguished by their different degrees of hardness. Stilbite loses about 19 per cent. of its weight when heated to redness, boils up under the blowpipe, and readily fuses into a white enamel. Hydrochloric acid dissolves it with separation of pulverulent silica. It is a hydrated silicate of alumina and lime, and may be represented by the formula $Al_2Ca\ Si_6O_{16} + 6\ H_2O$, which, if simplified, would be $\overbrace{Al : Ca}\ Si_3O_8 + 6\ H_2O$, or a hydrated labrador felspar.

Fig. 57.

Stilbite is found in many rocks and localities; amongst others in amygdaloid in the Faroe Islands, associated with apophyllite, mesolite, and heulandite; at Kirkpatrick, Scotland; Antrim, Ireland; at Theiss, in the Tyrol; and at many other places.

Heulandite.

Its primary form is an oblique rhombic prism with an angle of 136° 4′. The lustre is vitreous on all the faces but that of easiest cleavage, which is pearly; the colour of the crystals is white, grey, yellow, brown, and red, while that of the powder is white; and the hardness and sp. gr. essentially the same as in stilbite. It behaves much like it before the blowpipe and towards acids; is found in the same rocks, being frequently associated with it; and is, like it, a hydrated silicate of alumina and lime. Its formula differs in containing 1 atom less of water. *Epistilbite* is a soda-containing variety.

HARMOTOME. (*Syn.* Cross Stone; White Hyacinth; Morvenite; Andreolite.)

The primary form is a right rhombic prism of 124° 47′, and the crystals are frequently arranged in the form of a cross. The lustre is vitreous; the colour of the crystals white, yellowish, brownish, or reddish, that of the powder being white; the hardness 4·5; and the sp. gr. 2·4. When heated by the blowpipe it becomes white and friable, and melts with difficulty, on the edges, into a semi-transparent glass. It dissolves in hydrochloric acid with separation of pulverulent silica. It is a hydrated silicate of alumina and baryta corresponding to the formula $Ba\ Al_2\ Si_5O_{14} + 5\ H_2O$.

Its crystals are always macled, Fig. 58, and are chiefly found in veins traversing crystalline schists associated with galena, blende, quartz, barytine, &c.; it also occurs in aphanite at Przibram in Bohemia, and Hruschau in Silesia; in trachytes at Marienberg in Bohemia; in an amygdaloid at Oberstein, Dumbarton in Scotland, and Vicenza in Venetia; and in basalts at Schuna and Hauenstein in Bohemia.

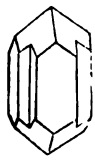

Fig. 58.

PHILLIPSITE. (*Syn.* Christianite; Lime Harmotome.)

The primary form is a right rhombic prism of 111° 15′, and, as in harmotome, the crystals are frequently grouped together crossways. The lustre is vitreous; the colour is absent, and sometimes bluish, greyish, or yellowish; the hardness 4·5; and the sp. gr. 2·17 to 2·20. It swells up and fuses into a white enamel under the heat of the blowpipe flame, and gelatinises with acids. It occurs in cavities in basaltic rocks and old lavas as small colourless translucid crystals, which are frequently grouped together in radiated agglomerations; as, for instance, at a locality near the Giant's Causeway, in Ireland; at Annerode, near Giessen; at Capo di Bove, near Rome; and at several other places. It is quite distinct from gismondine both in

chemical composition and in optical properties. It is a hydrated potash-lime silicate of alumina, somewhat analogous in composition to a leucite containing lime plus 5 atoms of water. Thus leucite is $K_2O.\ Al_2O_3.\ 4\ SiO_2$ or $\widetilde{K : Al}\ SiO_3$; and phillipsite is $\widetilde{K : Ca : Al}\ SiO_3 + aq.$, or $\widetilde{K_2 : Ca}\ O.\ Al_2O_3.\ 4\ SiO_2 + 5\ H_2O$.

Laumonite.

It is a hydrated silicate of alumina and lime, crystallising in yellowish columnar crystals derivable from an oblique rhombic prism with an angle of 86° 16′. Its lustre is vitreous, but sometimes pearly on the face of easiest cleavage; the colour of the crystal white, sometimes slightly tinged with yellow, grey, or red, and that of the powder is white. Its hardness is about 3·5 when fresh from its matrix, and its sp. gr. 2·29 (25,597) to 2·4 (26,827). Some specimens lose about 1 or 2 per cent. of water when exposed to the air, become opaque, and crumble to pieces; but others do not undergo this change. It may be prevented, though not always, by giving them a coating of gum arabic; but the best preservative is a damp atmosphere. It resembles the other zeolites in its behaviour before the blowpipe and towards acids. It is found in basaltic rocks, in syenite, in porphyry, in mica schists, and other crystalline rocks, and is usually associated with various zeolites, such as prehnite, as also with calcspar, orthoclase, epidote, and ripidolite. The formula assigned to it is $CaO.\ Al_2O_3.\ 4\ SiO_2 + 4\ H_2O$.

Analcime. (*Syn.* Cubicite; Sarcolite.)

It crystallises sometimes in cubes having the angles modified as in Fig. 17, Pl. I., and sometimes in forms such as would result if these modifying faces were extended until they intersected, as represented in Fig. 18, Pl. I. The formula for analcime is $Na_2O.\ Al_2O_3.\ 4\ SiO_2 + 2\ H_2O$. It is found at various localities in basaltic and

doleritic rocks, associated with other zeolites, such as mesotype, apophyllite, chabasite, &c.; it is also found in the plutonic rocks, such as zircon-syenite, and gneiss. The larger crystals are generally of a rosy hue, and occur in various parts of the Alps in melaphyre; at Dumbarton and other places in Scotland; at Glenarm and other places in Ireland; and in other countries. The smaller ones are usually brilliant and transparent. Analcime becomes electrical when rubbed; its hardness is about 5, and its sp. gr. is 2 to 2·2.

Chabasite. (*Syn.* Phacolite.)

Occurs in obtuse rhombohedrons with an angle of 94° 46′, sometimes modified on the terminal edges. They are transparent and colourless, or tinged with red and yellow. Its hardness is 4·5, and its sp. gr. 2·1. It is a hydrated silicate of alumina and lime, and its formula is $CaO.\ Al_2O_3.\ 4\ SiO_2 + 6\ H_2O$, so that it differs chemically from laumonite by containing a little more water. *Haydenite* and *Acadiolite* are varieties.

Pennine.

The name *Chlorite* was formerly applied to a group of minerals having certain characters in common which are now usually considered to be three distinct species, under the names of *pennine, clinochlore,* and *ripidolite.* The primary form of pennine is an acute rhombohedron with an angle of 65° 28′. It occurs in small transparent crystals and in thin plates. The lustre is vitreous, with a slight inclination to pearly on the basal faces. The colour is a dark green on the faces of the larger crystals, and light green on their bases; while the powder is a greenish white. The hardness is 2·5 on the basal face, and about 3 on the other faces; and the sp. gr. is 2·65. Before the blowpipe it exfoliates, whitens, and melts with difficulty into a greyish enamel. It is soluble in hydrochloric acid when powdered, and after long boiling. It is a hydrated silicate of alumina and magnesia, and is generally found in association with garnets and idocrase in chloritic

schist and serpentinous rocks. *Leuchtenbergite* is chemically very similar to pennine, and appears to be a pseudomorph after talc.

Clinochlore.

The primary form is an oblique rhombic prism with an angle of 125° 37′. In colour, hardness, specific gravity, behaviour before the blowpipe and towards acids, and chemical composition, it closely resembles pennine. It differs in containing a larger proportion of alumina.

Ripidolite.

It is not known to what crystallographical system this mineral belongs, but it is usually found in hexagonal tables, having a remarkably easy cleavage parallel to the base. They occur as thin greenish flakes in various schists. Their hardness is 1 to 2; and their sp. gr. from 2·78 (31,074) to 2·96 (33,086). When heated by the blowpipe they melt on the edges into a black magnetic slag. They are frequently found on crystals of adularia and quartz, or lining cavities in gneiss. The principal localities are St. Gothard; Greiner, in the Tyrol; Gumuch-Dagh, in Asia Minor, associated with emery; Bute, in Scotland; and in North Carolina. It is a hydrated silicate of alumina and iron.

Agalmatolite. (*Syn.* Bildstein.)

A name given to a variety of soft minerals on account of their having been employed by the Chinese as a material out of which to carve grotesque figures. They have the common characters of being hydrated silicates of alumina, containing variable proportions of potash, soda, or substances isomorphous therewith. The chemical composition of the Chinese variety is represented by the formula $9\ SiO_2.\ 3\ Al_2O_3.\ K_2O + 3\ H_2O$. The variety from Nagyag has the same composition; while that of the variety from Ochsenkopf, in Saxony, is expressed by the formula $9\ SiO_2.\ 3\ Al_2O_3.\ 2\ M^3O + 3\ H_2O$, in which M_2 denotes a certain proportion of sodium, potassium,

calcium, or magnesium. There are several minerals, such as *disyntribite*, *kaolin*, *stilbite*, and *neolite*, which closely resemble the agalmatolites in some of their physical properties, but their chemical composition is different. Agalmatolite has been found in England, Wales, and Ireland.

TOURMALINE. (*Syn.* Schorl; Rubellite; Apyrite.)

The tourmalines are a group of minerals which, with the same crystalline form and optical properties, present a great variety as regards colour, specific gravity, behaviour towards the blowpipe, and the proportions of their constituents. They all contain about the same amount of alumina and silica, but they differ in the proportion of the secondary oxides.

The primary crystalline form is an obtuse rhombohedron with an angle of 133° 8′, and the derivative forms are remarkable for their hemihedral modifications, in which only one-half the full number of faces are shown. When all the six faces of the primary rhombohedron are present three of them are striated, while the other three are smooth. When the prism represented in Fig. 59 is developed, the three alternate faces of the summit are larger than the others. Fig. 60 is another form of crystal. Tourmaline has a hardness of about 7·5; an uneven or imperfectly conchoidal fracture; and a sp. gr. ranging from 2·9 (32,416) to 3·2 (35,669). There are varieties of form, varieties of colour, and varieties distinguished by differences of chemical composition. Rammelsberg has formed five groups, viz. (1), the *magnesian* tourmalines, which contain a considerable proportion of magnesia, and are generally of a yellowish or brownish colour; (2), the *ferro-magnesian* tourmalines, in which the proportion of the ferric oxide is rather less than that of magnesia; (3), the *iron* tourmalines (schorl), in which the oxides of iron largely preponderate over the magnesia, and whose colour is nearly black; (4), the *iron-manganese-lithia* tourmalines,

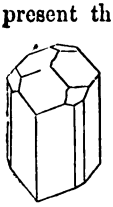

Fig. 59.

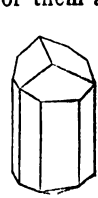

Fig. 60.

which usually have a blue or green colour; and (5), the *manganese-lithia* tourmalines (rubellite), which contain no iron, and whose colour is frequently roseate or deep red. Chemically, tourmaline may be considered to be a borosilicate of aluminium and of magnesia, soda, or lithia. The alumina may be partially replaced by ferric oxide, while the magnesia and soda may be partially replaced by ferrous oxide or the protoxide of manganese.

It is eminently pyroelectric, and often shows marked dichroism; thus, specimens are yellowish-brown in one direction, and green in another; or dark brown in one direction and greenish-blue in a second; and others offer additional variations. Some crystals, such as those of Elba, have the two summits of different colours, such as green and blue. Again, some crystals are transparent when looked through in a direction at right angles to the axis of the prisms, but opaque when looked through lengthwise. Most varieties intumesce before the blowpipe, and yield slags varying in colour from white, through shades of yellow, green, and brown, to black. The red manganesian varieties exfoliate, turn opaque, and become white.

Tourmaline is widely distributed. It is generally found in granites, mica schists, and gneiss; also in dolomites and granular limestones. Colourless tourmalines occur at St. Gothard and Isle of Elba; red ones in Siberia, at Paris in Maine, United States, at Chesterfield and Goshen in Massachusetts, in Saxony, and Peru; yellow varieties at Imfield in the Binnenthal, and at Fitzroy in Canada; brown varieties in Spain, United States, Canada, Styria, and Ceylon; green varieties in Saxony, Moravia, the Alps, United States, Brazil, Madagascar, and Ceylon; blue varieties (indicolite) in Sweden, the Ural Mountains, the United States, and Brazil; black varieties at various localities on the Continent, at St. Just in Cornwall, at Bovey Tracey in Devonshire, and in America; Cornwall also has the colourless kind.

AXINITE. (*Syn.* Thumerstein; Yanolit; Glass Schorl.)

This mineral usually crystallises in very flat oblique

triclinic prisms. Its lustre is vitreous, its colour is brownish-purple, pearl-grey, and sometimes greenish in the crystalline state, but always white when powdered. It is more or less polychroic, being cinnamon-brown, violet-blue, or olive-green, according to the direction in which it is looked through. The violet tint occurs as a bar interrupted at the point where it intersects one of the optic axes. The hardness is 6·5 to 7, and the sp. gr. 3·2. It is pyroelectric, readily melts into a pearly-green glass which blackens if held in the oxidation flame, and is soluble after fusion in hydrochloric acid, with separation of gelatinous silica. It is a boro-silicate of alumina and lime. It occurs in crystals and small lumps in granite, gneiss, mica schist, diorite, and is associated with quartz, orthoclase, albite, epidote, tourmaline, and ripidolite, which last often penetrates it so as to give it a green tint. Fine specimens have been brought from St. Christophe, in the department of the Isère.

Datholite.

The primary form is an oblique rhombic prism, with angles of 76° 36′ and 89° 56′; and the crystals are usually very small and brilliant. The colour is greyish, greenish, or reddish white, the lustre vitreous, the fracture imperfectly conchoidal, the hardness 5 to 5·5, and the sp. gr. 2·8 to 3. When heated in a tube it gives off water; and with the blowpipe it swells up before melting into a green glass. The presence of boron is indicated by its colouring the flame a yellowish-green, which phenomenon is an exceedingly delicate test for boron, provided copper is known to be absent. It readily dissolves in hydrochloric acid with separation of gelatinous silica. Its formula, according to Rammelsberg, is $CaO.B_2O_3 + CaO.2SiO + aq.$, or that of a hydrated boro-silicate of lime; it may also be represented by the simpler expression $\overbrace{B:Ca}:HSiO_3$. It generally occurs in basaltic rocks, and is found in the Kilpatrick Hills, Salisbury Craig, and Corstorphine Hill, in Scotland; at Arendal, in Norway;

at Monte Catini, in Tuscany; near New Haven, Connecticut, United States; and in other localities. *Botryolite* is an amorphous variety of datholite, and contains rather more water. It is found at Arendal associated with magnetic iron, tourmaline, hyaline quartz, and calcspar.

LAPIS LAZULI. (*Syn.* Ultramarine.)

It crystallises in the cubic system, but the only forms yet found are the rhombic dodecahedron and the ordinary dodecahedron. It is, however, seldom met with in the crystalline state, but generally forms compact masses, with a laminated structure in some of the granular limestones which traverse granites and argillaceous schists. These masses are usually associated with iron pyrites and mica. It is feebly translucent, and possesses a characteristic blue tint, which is probably due to some combination of sulphur with sodium and iron. The lustre is vitreous, but very dull, the fracture is uneven conchoidal, the hardness 5·5, and the sp. gr. 2·3 to 2·45. It fuses before the blowpipe into a white glass, and when powdered, readily dissolves in hydrochloric acid, with the loss of its colour and the separation of its silica in a gelatinous state. This mineral was formerly the source of ultramarine blue, but large quantities of this substance are now made artificially at a far cheaper rate than it could be obtained from the native mineral. Many French writers call this mineral lazulite, but this term is usually applied to another blue stone, which is a hydrated phosphate of aluminium and magnesium. Lapis lazuli is not a distinct mineral species, but is a mixture of several. It is found in Persia, Thibet, Bokhara, China, and in the Argentine Republic of South America.

HAUYNE is similar to lapis lazuli in its crystalline form, its blue colour, its hardness, and indeed in most of its properties, but its specific gravity is a little higher. It appears to be a silico-sulphate of alumina, soda, and lime, analogous to sodalite and nosean.

SODALITE is a silicate of alumina and soda combined

with chloride of sodium, and may be represented by the formula $Na_2O.Al_2O_3\,2\,SiO_2+NaCl$, or more simply by

$\widetilde{Na}:Al.\,SiO_3$, with a variable quantity of chloride of sodium. It crystallises in rhombic dodecahedrons, which may be more or less modified by the faces of the cube or trapezohedron. It is sometimes colourless, and sometimes green or azure blue. The hardness is 5·5, and the sp. gr. 2·29 to 2·35. It fuses into a colourless glass. It was originally found in Greenland, associated with garnet and arfwedsonite; but it has since been found at Mount Vesuvius, and in many ancient lava streams and metamorphic rocks. The blue varieties have been found in the Ural Mountains, in Norway, and in the United States. Sodalite or nepheline are invariably present in the Vesuvian lavas erupted between 1631 and 1868.

Nosean is closely allied to hauyne and sodalite, and like them is chiefly found in eruptive rocks.

Ardennite.

A silicate of alumina and manganese, containing a large proportion of vanadic and arsenic acids. It crystallises in trimetric forms. Hardness 6·7; sp. gr. 3·62; colour yellow to yellowish-brown; thin splinters are translucent and dichroic, being red in certain directions. Very brittle. It fuses with ease to a black glass. Found near Ottrez, in the Ardennes, with quartz and albite.

Haughtonite.

Dr. Heddle has given this name to certain minerals which were or would have formerly been assigned to biotite. It chemically differs from the more typical biotites by the iron being mainly in the *ferrous* condition, and by the subordination of the magnesia to the oxides of iron. It occurs in the older Scotch granites, gneiss, and diorites, forming tough highly-lustred black scales, having a sp. gr. of about 3. Some of the crystals are a foot or more in length.

Hydrobiotite.

By exposure to the atmosphere biotite sometimes passes into the hydrated form, for which the name hydrobiotite has been proposed. The alteration is accompanied by a change of colour from black to brown. It bears the same relation to biotite as margarodite does to muscovite. As brown biotites have often been recorded, it is probable that hydrobiotites may be found at most of the localities where these have been met with.

Barylite.

It is a baryta felspar, crystallising in groups of prismatic crystals, having a more or less tabular habit, and cleaving in two directions which form an angle of about 85°, indicating that they belong to the triclinic system. Hardness 7; sp. gr. 4·03; lustre greasy; colourless, and semi-transparent. It is infusible by the blowpipe and insoluble in acids. It is associated with mimetesite in the crystalline limestone at Långban, Wermland, Sweden.

Microcline.

This name was formerly given to a variety of orthoclase. An examination of some of these indicated that, although they had the same chemical composition, they were distinctly triclinic; and hence Des Cloizeaux has adopted the name for a species comprising all the triclinic potash felspars. Breithaupt had noticed the slight inclination of the axes, and hence the name he gave it. Other mineralogists had observed it, but as it was so slight it was placed under orthoclase. In some of its optical properties it is readily distinguishable from typical orthoclase. Owing to polysynthetic twining, it presents striæ like triclinic crystals; and under polarized light it shows a characteristic grating-like structure, caused by the regular growth of twin laminæ; some of these laminæ are orthoclase, others albite. It is obtained in large quantities at Branchville, Connecticut, some of the cleavage surfaces having a length of ten feet. It is also found in many localities, since

nearly all the potash felspars formerly designated orthoclase belong to microcline.

Eucryptite.

It is a lithia felspar, to which the formula $\overset{\frown}{\text{Li}} : \text{Al. Si } O_4$ may be assigned. It has not been found yet in the free crystallised state like other felspars, but combined with albite as an alteration product of spodumene. Both minerals are white, and hence it was difficult to detect the eucryptite, which has its name from being so well concealed. Eucryptite, however, is soluble, whereas the albite is not; and in this way the imbedded crystals of eucryptite can be removed in solution. Under the microscope, with polarized light, the two minerals can also be readily distinguished. It is found at Branchville, in Connecticut.

Danburite.

It is considered by some to be a boron-felspar. It crystallises in the trimetric system, in forms which are almost precisely like those of topaz, which mineral it also resembles in its pale wine colour, honey yellow, and yellowish-brown tints, its transparency, its brilliant lustre, and its unevenness to subconchoidal fracture. Chemically it is very different, as also in its hardness, which is 7—7·25, and in its sp. gr., which is 2·9 to 3·0. It occurs in small brilliant crystals imbedded in calcite, and also in large crystals in cavities from which the calcite has been weathered out, in association with quartz, mica, pyroxene, and titanite. The large crystals found at Russell, New York, and on the Skopi, in Switzerland, are most deceptively like topaz.

Talcosite.

A hydrated silicate of alumina, containing less water than kaolin. It derives its name from its close external resemblance to talc, occurring, as it does, in scaly rhombic plates, which are silvery white or greenish in colour, pearly in lustre, and flexible, but not elastic.

It is from Mount Ida, near Heathcote, Victoria, where it is associated with selwynite. The hardness is 1—2, or rather more than that of talc; and the sp. gr. 2·4—2·5, which is rather less than in talc.

Pilolite.

Mountain cork and *mountain leather* have usually been regarded as varieties of tremolite; but Professor Heddle finds, from an examination of Scotch specimens, that they do not belong to that species, but rather form a distinct species near the clays and halloysite. Chemically, pilolite seems to be a hydrated silicate of magnesia and alumina. It is slightly yellow, has a densely felted structure, the fibres being tough and long. It occurs in limestone, granite, conglomerate, and slate.

CHAPTER X.

Tantalates, Niobates, Zirconates, Tungstates, Vanadates, and Chromates.

Tantalite. ($FeO.2\,TaO_2$. *Syn.* Ixiolite.)

This is a black heavy mineral, having a sp. gr. of 7·1 (79,963) to 7·9 (88,306), and a hardness of 6 to 6·5. The crystals are rare, and are derivable from a right rhombic prism with an angle of 122° 54′. They are generally elongated imperfect crystals, presenting very little lustre. It is a bitantalate of iron, but the ferrous oxide is frequently more or less replaced by the protoxide of manganese, and the tantalic acid by stannic (SnO_2), or zirconic acids (ZrO_2). It is found in small lumps in granites and pegmatites in Finland, Sweden, and near Limoges, in France. This name was formerly given to specimens from Bavaria and America, which are now known to be quite distinct. They belong to columbite.

Columbite. (*Syn.* Niobite; Tantalite of Bavaria and America; Baierine.)

As the atomic weight of niobium is not quite settled, there is a difficulty as to what formula is correct. Colum-

bite is usually regarded as a niobite of iron and manganese ($FeO : MnO . Nb_2O_5$). Its colour is black, its hardness is between 5 and 6, or rather less than that of tantalite. Its crystals are trimetric prisms, and are found in granitic rocks associated with beryl or with cryolite. It is infusible by the blowpipe, and acids have no effect upon it.

EUDIALYTE is a brownish-red lamellar mineral from Kangerdluarsuk, in Greenland, where it is associated with sodalite and arfwedsonite in gneiss. The crystals are rare; they belong to the hexagonal system, and are either acute rhombohedrons with an angle of 73° 30′, or derived therefrom. Their hardness is 5 or 5·5, and their sp. gr. 2·9. It is a zirco-silicate of iron, soda, and lime ($\overbrace{Fe : Na : CaO}. 2 \overbrace{Si : ZrO_2}$). It is readily fused into a dark glass, and dissolves in acids with separation of gelatinous silica. The *eukolyte*, from the zircon syenite, appears to be a eudialyte containing a little of the oxides of cerium and lanthanum.

SPHENE. (*Syn.* Titanite.)

This is a silico-titanate of lime. It crystallises in the monoclinic system, the primary form being, according to Rose, an oblique rhombic prism, having the vertical faces inclined towards each other at an angle of 76° 2′, and towards the base at an angle of 93° 1′. The form of the crystals is, however, exceedingly variable; they generally present a brilliant adamantine lustre, and a yellowish or brownish colour. The hardness is 5·5, and the sp. gr. 3·4 to 3·6. Sphene becomes electrical when heated; fuses readily before the blowpipe into a dark glass, and is entirely decomposed by sulphuric acid with formation of gypsum or sulphate of lime. It occurs in the mica schist of the Alps; in the granite of Bavaria and Greenland; in the gneiss of Massachusetts; in the syenites and zircon syenites of Norway and Argyleshire; in the saccharoidal limestone of France and the United States; in the trachytes, phonolites, and older lava

streams of Auvergne, Bohemia, and Rhenish Prussia; and in beds of magnetic iron ore in Norway.

There are several varieties: thus *spinthere* is a greenish-grey sphene; *pictite*, a violet sphene; *ligurite*, is a greenish-yellow variety; and *greenovite* is a red variety containing protoxide of manganese.

YTTROTANTALITE occurs in grains or imperfect crystals in the granitic rocks at Ytterby, Finbo, and Kararfvet, near Fahlun, in Sweden. There are three varieties, which differ in colour and composition. The first variety is of a pale green colour; it has a vitreo-resinous lustre, a hardness of 4·5 to 5, and a sp. gr. of 5·3 to 5·8. It does not dissolve when heated with carbonate of soda. The second variety is black; it has a metallic lustre, a hardness greater than that of glass, and a sp. gr. of 5·39. It is dissolved when heated with carbonate of soda. The third variety has a brownish-yellow colour; it does not scratch glass, and its sp. gr. is 5·88. All are insoluble in acids, but are decomposed by them after they have been fused with bisulphate of potash. All are tantalates of yttria; but the first is quadribasic; the second and third are tribasic. The yttria is usually more or less replaced by lime, ferrous oxide, and oxide of uranium; and the tantalic acid by tungstic acid.

POLYMIGNITE is an iron-black mineral, having a metallic lustre, and crystallising in long trimetric prisms. Its hardness is 6·5, its sp. gr. is 4·8, and it is composed of zirconia, titanic acid, yttria, oxide of cerium, peroxide of iron, lime, and a few other substances in small proportions. Its formula has not been satisfactorily determined. It is infusible by the blowpipe, soluble in sulphuric acid, and is found in the zircon syenite of Frederickswärn, in Norway.

PYROCHLORE is found in small grains or regular octahedrons in the zircon syenite of Frederickswärn and Laurwig, in Norway. Its hardness is 5·5, and its sp. gr. 4·21. The colour is pale yellow or blackish-brown; the lustre

is vitreous or resinous, and the fracture conchoidal. Its composition is variable, but it appears to be an impure niobate of some protoxide, such as lime, thorina, &c. *Euxenite*, *Æschynite*, and *Polycrase* are similar minerals. *Microlite* is a pale yellow variety.

Scheelite is a tungstate of lime ($CaO.WO_3$), which crystallises in octahedrons derivable from a quadratic prism. Its colour is white or yellowish, its lustre is vitreous, slightly inclined towards resinous, its hardness is 4·5, and its sp. gr. 6·0. It is fused with difficulty by the blowpipe, and is slowly attacked by nitric acid, which decomposes it with separation of the tungstic acid. It is generally found in metallic lodes, especially such as contain tin; and its principal localities are the tin mines of Cornwall, Saxony, and Bohemia; it is also met with in some iron and manganese mines, and in veins containing bismuth at Huntington, in Connecticut.

Stolzite. ($PbO.WO_3$. *Syn.* Scheelitine.)

The native tungstate of lead resembles scheelite in its chemical constitution, in occurring in quadratic octahedrons, and in being associated with oxide of tin. Its hardness is 3, its sp. gr. 8 (89,424), its lustre resinous, and its fracture conchoidal. The blowpipe flame readily fuses it, and nitric acid dissolves it with separation of tungstic acid. It is found in the tin mines of Zinnwald, Bohemia, associated with quartz and mica, and at Bleiberg, in Carinthia, associated with molybdate of lead.

Wolfram. ($\overline{Fe:Mn}O.WO_3$. *Syn.* Tungstate of Iron and Manganese.)

This is a heavy mineral, having a dark brown colour and a semi-metallic lustre. It affords cleavage in directions which seem to indicate that its primary form is a right, or slightly oblique, rhombic prism. It resembles bronzite and amorphous blende, but its high sp. gr., 7·5 (83,845), readily distinguishes it from both. It is common in many of the Cornish and Saxon mines; the rock in

which it is found is generally pegmatite or gneiss, and the minerals associated with it are scheelite, topaz, beryl, and cassiterite. Wolfram is the principal source of tungstic acid, of which it contains nearly 76 per cent.

Wulfenite.

It occurs in octahedrons belonging to the dimetric or quadratic system, and in flat tables. (Figs. 2 and 3, Pl. II.) It is brittle, has a yellowish colour, a vitreous lustre, and is isomorphous with scheelite. The crystals cleave readily parallel to the faces of the principal octahedron. Its hardness is 3, or less than scheelite; while its sp. gr. is 6·9 (77,128), or rather greater than that of the same mineral. When fused by the blowpipe it yields a globule of lead; and when dissolved in nitric acid a white powder separates, which is turned blue when touched with zinc. It is a molybdate of lead, to which the formula $PbO.MO_3$ may be assigned. It is found in a compact limestone at Bleiberg and Windisch-Kappel; as also in Hungary, Mexico, and Pennsylvania.

Dechenite. (*Syn.* Eusynchite.)

It occurs as a reddish substance yielding a yellow powder in a sandstone near Niederschlettenbach, in Rhenish Bavaria; it is usually in botryoidal lumps, having a crystalline structure, and apparently composed of an aggregation of minute rhombic prisms or rhombohedrons. The cleavages seem to favour the opinion that they are of the latter form. Its hardness is 4, and its sp. gr. 5·8. Before the blowpipe it fuses into a greyish pearly glass, and yields a globule of lead. It dissolves in nitric and hydrochloric acids; the former solution is yellow, and the latter green. With the last-mentioned acid there is a separation of chloride of lead.

Descloizite.

This mineral occurs in black or dark green lumps enclosed in a reddish clay in some of the lead mines of La Plata. These lumps are composed of minute crystals,

having the form of rhombic octahedrons derivable from a rhombic prism with an angle of 116° 25′. It is fusible before the blowpipe into a black slag, and yields a colourless solution with nitric acid. It is probably a vanadate of lead, having the formula 2 PbO. VO_3.

Volborthite.

A vanadate of copper and lime from the copper mines of Sissersk and other places in Russia, and of Frederichsrode, in Thuringia. It usually occurs in spheroidal aggregations, built up of olive-green hexagonal tables. Before the blowpipe it yields a black slag, which, by further heating, gives a globule of copper. It dissolves in nitric acid, with separation of vanadic acid, yielding a green solution. The varieties containing lime are sometimes called *Kalkvolborthite*.

Vanadinite.

This appears to be a vanadate of lead combined with chloride of lead, or 3 (3 PbO. VO_3) + PbCl. It crystallises in minute hexahedral prisms, having a yellowish-white or fine ruby-red colour. The lustre is resinous, the hardness 3, and the sp. gr. about 7 (78,246). Before the blowpipe it first decrepitates, and after a somewhat prolonged application of the heat yields a few grains of lead. It is soluble in nitric acid, yielding a yellow solution. It has been found in spheroidal masses in the mines at Zimapan, Mexico, associated with other lead ores; as also at Wanlock Head, in Scotland; in Yuma co., California; at Windisch-Kappel, in Carinthia; and at Beresof, in Siberia.

Crocoisite. (*Syn.* Red Lead.)

The native chromate of lead (PbO. Cr_2O_3) is the same substance as the *chrome yellow* so much used for painting carriages, &c. It crystallises in forms derivable from an oblique rhombic prism, in which the vertical faces are inclined towards each other at an angle of 93° 30′, and towards the base at an angle of 99° 10′. The crystals are of a beautiful hyacinth-red colour, while the powder

is orange-yellow. The lustre is vitreous, the hardness about 3, and the sp. gr. 5·9 to 6·1.

It is rather rare; and for a long time the only locality known was at Beresof, in the Ural Mountains; its crystals are met with in veins in a talcose gneiss and in micaceous quartzites. Amongst its other localities are Nischne Tagilsk; at Congonhas do Campo, in Minas Geraes province; in Hungary; and in Brazil.

Melanochroite. (*Syn.* Phœnicite.)

This is a basic chromate of lead, which differs from crocoisite by its chemical composition, its tint, and its form. According to Hermann, it is composed of 23·6 per cent. by weight of chromic acid, and 76·4 of oxide of lead, which nearly corresponds to the formula 2 PbO. Cr_2O_3, or $\overbrace{Pb : CrO_2}$. It crystallises in rhombic prisms, which apparently belong to the trimetric system; the crystals are exceedingly small, and are generally interlaced together so as to form a kind of network. The colour is hyacinth-red, the lustre resinous or adamantine, the hardness 3 to 3·5, and the sp. gr. 5·75 (64,273). When treated with the reducing flame of the blowpipe it yields a globule of lead. It is found in a limestone at Beresof, in the Ural Mountains, associated with crocoisite, vauquelinite, galena, and pyromorphite.

Vauquelinite.

It accompanies the foregoing species as a dark green powder or incrustation, composed of minute crystals belonging to the monoclinic system. The fracture is uneven, the lustre resinous, the hardness 2·5 to 3, and the sp. gr. 5·5 to 5·7. It resembles melanochroite in chemical constitution, differing from it in containing a little oxide of copper in place of some of the oxide of lead. When fused on charcoal it yields a dark grey metallic globule, which sometimes contains a few specks of reduced lead. It readily dissolves in nitric acid with

formation of a yellow solution. It is found along with crocoisite at most of the localities where that mineral occurs. At the Pequa lead mine in Lancaster co., Pennsylvania, it occurs in apple-green crystals associated with cerussite on quartz and galena.

Jossaite is an allied form found along with vauquelinite at Beresof, in Siberia.

PEROFSKITE. ($CaO\ TiO_2$. *Syn.* Leucoxene; Titanomorphite.)

The crystals of this titanate of lime are probably isometric. Hardness 5·5; sp. gr. 4; colour various shades of yellow and brown to black. It is found at Achmatowsk, in the Zermatt valley; Wildkreuzjoch; Magnet Cove, Arkansas; and in large masses in the amphibolite of Hohe Eule.

EOSITE.

It appears to be a vanadio-molybdate of lead, which crystallises in minute octahedrons belonging to the dimetric system. The hardness is 3—4, and the colour deep aurora red. Found on pyromorphite and cerussite at Leadhills, Scotland.

HÜBNERITE.

A tungstate of manganese crystallising in trimetric crystals which have a hardness of 4·5; a sp. gr. of 7·14; an adamantine lustre on the cleavage faces; a brownish red colour, and an uneven fracture. It forms a vein three to four feet thick in the Monmouth district, Nevada, associated with scheelite, fluorspar and apatite.

PATERAITE.

This name has been given to an impure and ill-defined mineral which may be noticed as indicating the

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probable existence of molybdate of cobalt as a mineral. It was found by Vogl in the Elias mine, Joachimsthal, associated with uranium ores.

CHAPTER XI.

Sulphates, Nitrates, Phosphates.

Thenardite. (Na_2SO_4.)

It is an anhydrous sulphate of soda. It crystallises in rhombic rhombohedrons derivable from a right rhombic prism, with an angle of 129°. The colour is white, the lustre vitreous, the hardness 2·5, and the sp. gr. 2·6 to 2·73. When exposed to the air it effloresces, and when heated before the blowpipe it colours the flame yellow. It is completely soluble in water. It is present in a deposit from some saline springs near Madrid, and has also been found by Scacchi amongst the volcanic *débris* of Vesuvius. Tarapaca, in Peru, is a third locality, and there it is associated with glauberite and hayesine.

Glaserite. (K_2SO_4. *Syn.* Arcanite.)

Like thenardite it is white; but some of the more impure specimens are tinged yellowish or bluish; its lustre is vitreous, inclining to resinous; and it crystallises in thin tables derivable from a rhombic prism of 120° 24′. It is not altered by exposure to the air, it does not yield water when calcined, and it fuses without intumescing. It has been found in small quantities as a lining to cavities in recently-ejected lavas. An impure variety has also been discovered in the guano of the Chincha Islands.

Mascagnine. ($(NH_4)_2\ SO_4$.)

This is a native sulphate of ammonium isomorphous with glaserite. Its crystals are six-sided prisms terminated by pyramidal summits, and are derivable from a rhombic prism of 121° 8′. It is soluble in water, occurring

in the waters of some of the Tuscan lagoons, but is also found solid as a white, bitter, pungent, efflorescent substance on the lavas of Vesuvius, Etna, and the Lipari Islands. Its hardness is 2·25, and its sp. gr. 1·72. The artificial sulphate of ammonia is used as a manure, and in the manufacture of ammonia-alum.

ANHYDRITE. ($CaSO_4$. *Syn.* Karstenite; Muriacite; Vulpinite; Cube Spar.)

This mineral seldom occurs in crystals; but when these do occur they are generally rectangular prisms variously modified on the edges. It possesses distinct cleavage in three directions, and hence readily divides into tabular blocks. The plane of easiest cleavage presents a pearly, while the faces produced by the other cleavages have a vitreous, lustre, which is rather duller in one than the other. The purer specimens are colourless and transparent, but the less pure ones are greyish, or present various tints of blue, rose, and violet. It possesses double refraction, and the apparent angle of the two axes is 75° 5′. The hardness is 3·5, or greater than that of gypsum; its sp. gr. is 2·8 to 3. When heated it does not become opaque white, nor does it exfoliate as gypsum does. It is sparingly soluble in water and in acids. There are several varieties of structure and form; as, for instance, the blue saccharoidal anhydrite of Wurtemberg, which is much used for ornamental objects; the contorted variety, from Wieliczka, sometimes called *tripe-stone;* the fibrous variety, from Halle, in the Tyrol; and others. *Muriacite* is a variety with a little chloride of sodium, and *Vulpinite* contains a considerable proportion of silica. It generally occurs under the same conditions as gypsum; and when it is exposed to the open air, it frequently passes into that mineral by absorption of water. It is very common in metalliferous lodes and in saliferous deposits.

CELESTINE. ($SrSO_4$.)

In many respects this mineral has a close resemblance to barytine. Its crystals are derivable from a right rhombic

prism of 103° 58′, having its easiest cleavage parallel to the base, Fig. 61. The colour is various shades of grey, yellow, red, and blue; the lustre is vitreous; the hardness 3·5; and the sp. gr. 3·9 (43,494). Before the blowpipe it melts with difficulty into a milky-white enamel; and when subjected to the reducing flame strontia is obtained. When moistened with hydrochloric acid after fusion with soda and charcoal, it colours the flame carmine red, a test which distinguishes it from barytine. There are many varieties. Thus, the celestine of Bristol is generally lamellar or fibrous; that at Montmartre is acicular. *Baryto-celestine* is a variety containing baryta, found at Kingston in Canada, and in the dolomite of Binnenthal. Fine crystals of celestine are met with at Girgenti, in Sicily; Conil, in Spain; Bex, in Switzerland; Pyle Hill, near Bristol; and elsewhere. It is not so frequently met as barytine in mineral veins, and generally appears to be of more recent formation. Its principal situation is in the gypseous deposits associated with rock salt, gypsum, and sulphur, and in some of the older limestones of North America, such as those of the Trenton and Chazy formations.

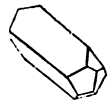

Fig. 61

BARYTINE. ($BaSO_4$. *Syn.* Heavy Spar; Barytes; Baroselenite.)

The primary form is a right rhombic prism of 101° 42′, readily cleaving in directions parallel to all its faces. Their usual form is in tables such as shown in Fig. 62, fine specimens of which occur in Cumberland, Durham, Derbyshire, and Somersetshire. The colour is generally white or yellowish, but it sometimes presents various shades of blue, green, red, and brown. The lustre is vitreous, the hardness 3·5, and the sp. gr. 4·5. It is with difficulty fusible into an opaque white enamel, and when heated in the inner flame it is decomposed and reduced to the state of a sulphide of barium. Neither acids nor alkaline carbonates have any

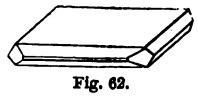

Fig. 62.

effect upon it. There are granular, lamellar, bacillar, radiated, concretionary, and compact varieties. The radiated barytine is found at Mount Paterno, near Bologna, and is remarkable for its phosphorescent power, either when heated alone, or with a little organic matter. Hence this variety is sometimes called *Bologna spar*, and the mixture with organic matter *Bologna phosphorus*. *Cawk* is the name given to the massive opaque earthy specimens, and *Hepatite* to those which emit a sulphurous fetid odour when rubbed. Barytine is very widely distributed, and is frequently associated with the various ores of lead, silver, mercury &c. There are several minerals which appear to be little more than impure varieties of barytine. Thus, *Kalkbaryt*, from Saxony and Derbyshire, contains a large proportion of sulphate of lime; *Dreelite*, from a lead mine near Beaujeu, contains sulphate and carbonate of lime; *Calstronbaryte*, from Schoharie, New York, contains carbonates of lime and strontian; and *Barystrontianite* contains carbonate of strontian.

Anglesite. ($PbSO_4$.)

This is the anhydrous sulphate of lead. It crystallises in rectangular octahedrons and tables derivable from a right rhombic prism of 103° 38′, so that it is nearly isomorphous with celestine. The crystals are generally colourless, but sometimes they are various shades of grey, brown, yellow, and green. The lustre is adamantine, the hardness 3, and the sp. gr. 6·3. It possesses double refraction, fuses in the blowpipe flame, and blackens when exposed to sulphuretted hydrogen. It is found, generally in minute crystals, in the lead and copper mines of Anglesea; at Wanlock, in Dumfries-shire, in crystals nearly two inches long; at Leadhills, in Lanarkshire; at Cromford, in Derbyshire; at Badenweiler, in Baden; at Phœnixville, in Pennsylvania; and elsewhere. It is generally associated with galena, from which it is derived by oxidation.

Gypsum. ($CaSO_4 + 2\,H_2O$. *Syn.* Selenite; Plaster-stone; Alabaster.)

Gypsum is a sulphate of lime combined with two atomic proportions of water, and differs in many respects from anhydrite. It generally occurs in a crystalline state, the primary form being a monoclinic prism. The crystals are frequently arranged in regular groups, and sometimes two are so arranged that their planes of easiest cleavage coincide, giving rise to the *arrow-headed* form shown in Fig. 63. There are three directions of cleavage. The faces produced by the first and easiest have a pearly lustre; those produced by the second are vitreous, inclined to scaly; while those produced by the third have a fibrous aspect. The direction of the latter two cleavages is generally represented by striæ. The crystals are usually colourless and transparent, but are sometimes brownish, yellowish, or reddish. It possesses double refraction. The hardness is 2, and the sp. gr. 2·3. When heated, the combined water is driven off; the crystals become opaque white, breaking up into a multitude of excessively thin flakes. *Selenite* is the name generally given to the crystalline form. *Fibrous* gypsum has a beautiful pearly or silky lustre; *saccharoidal* gypsum has a fine granular texture, like white marble, and is used in the East under the name of *alabaster*—a name also given to a carbonate of lime.

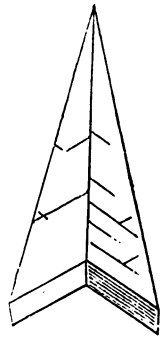

Fig. 63.

Sulphate of lime is the most widely distributed of all the sulphates. It is found in most rivers, lakes, and seas; in the strata of almost every country; and in formations ranging from the oldest crystalline rocks of Scandinavia up to the most modern argillaceous deposits. A bare list of all its localities would fill several pages, but the reader may find many mentioned in the works of Bristow, Bischof, Cotta, Delafosse, and others.

The mode of occurrence and range of distribution of both the hydrated variety (gypsum) and the anhydrous (anhydrite) are very similar. Its formation appears to take place in several ways, viz. (1), by deposition from concentrated salt waters, which may be either oceanic, lacustrine, or derived from mineral springs; (2), by the chemical action of iron pyrites on lime in moist strata; and (3), by the action of gaseous sulphur compounds, either in the free state or in solution, on rocks and minerals containing a large proportion of lime.

CYANOSITE. ($CuSO_4 + 5\,H_2O$. *Syn.* Blue Vitriol · Chalkanthite.)

This mineral has a beautiful blue colour, and usually occurs as a pulverulent powder or hard incrustation, seldom in distinct crystals, having a form more or less resembling Fig. 4, Pl. II. The lustre is vitreous, the fracture conchoidal, the hardness 2·5, and the sp. gr. 2·27. It is soluble in three times its own weight of cold water, yielding a blue solution, from which copper is deposited on the introduction of a steel blade. This mineral is derived from the decomposition of copper pyrites, and is abundant wherever water flows over the rubbish-heaps collected round copper mines, and where it flows from the workings in the mines. In many cases the copper is obtained by leading such waters through troughs containing scraps of iron.

EPSOMITE. ($MgSO_4 + 7\,H_2O$. *Syn.* Epsom Salt; Sulphate of Magnesia; Sel de Sedlitz.)

The hydrated sulphate of magnesia, containing seven atomic proportions of water, crystallises in right rhombic prisms with an angle of 90° 34′, and with more or less modified edges and angles, as in Fig. 37, Pl. II. Its most usual mode of occurrence is in crystalline efflorescences, in acicular groups, or in fibrous masses having a silky lustre like fibrous gypsum. It is a white, bitter-tasting salt, and soluble in water. It is found in solution in many mineral springs, such as those at Epsom, Sedlitz,

and elsewhere, as also in the waters of the ocean and of several lakes. Masses a foot in diameter have been found in the Alum Cave and other localities in Tennessee; in the Mammoth Cave of Kentucky; and smaller lumps near Madrid, in Spain; at Dundas, Niagara, and other parts of Canada; and in Hungary. *Astrakanite*, or *Blödite*, is a native hydrated sulphate of magnesia and soda associated with epsomite in the salt marshes near the mouth of the Volga.

MELANTERITE. ($FeSO_4 + 7\,H_2O$. *Syn.* Green Vitriol; Green Copperas.)

A bluish-green, inky-tasting, soluble substance, crystallising in forms derivable from an oblique rhombic prism. When exposed to the air it effloresces, and by the absorption of oxygen is partially converted into iron oxide. It occurs in incrustations having a fibrous structure, and in yellowish filaments lining the surfaces of schistose rocks, especially those which contain decomposing iron pyrites (marcasite). The sulphate of iron of commerce is mainly obtained artificially from iron pyrites, and specimens of this last mineral, when kept in moist air in cabinets, are often more or less changed into green copperas. Sulphate of iron unites with pyrogallic acid, giving rise to the compound familiarly known as ink.

Botryogene is another sulphate of iron, but of a far more complicated constitution. It has a hyacinth-red or yellowish-brown colour, and is sometimes called the *red* vitriol or sulphate of iron. It is, like the last, a decomposition product of marcasite; it crystallises in monoclinic prisms, which are generally grouped into botryoidal masses.

GOSLARITE. ($ZnSO_4 + 7\,H_2O$. *Syn.* White Vitriol; White Copperas.)

This is the native hydrated sulphate of zinc: there is also an anhydrous form, which is known as *Almagrerite*. The primary form of goslarite is a right rhombic prism of 91° 7′. It usually occurs in white needles or fibrous con-

cretionary masses in blende mines, such as those at Rammelsberg, near Goslar, and at Schemnitz, in Hungary. It is soluble in water, has a styptic or inky taste, and is derived from blende by decomposition.

BIEBERITE. ($CoSO_4+7\ H_2O$. *Syn.* Rose-coloured Vitriol; Cobalt Vitriol.)

This occurs under similar conditions as the other sulphates with seven atomic proportions of water; viz., as a lining on rocks in mines containing the sulphide of cobalt, from which it is derived by oxidation. The primary form is a monoclinic prism whose vertical faces are inclined towards each other at an angle of 82° 20′, and towards the base at an angle of 99° 45′. It has a pale rose-red colour, a bitter inky taste, a vitreous lustre, and is readily soluble in water. Its principal localities are Bieber, in Hesse; near Neusohl, in Hungary; and near Copiapo, in Chili.

MIRABILITE. ($Na_2SO_4+10\ H_2O$. *Syn.* Glauber Salt.)

The native hydrated sulphate of soda occurs in crystals derivable from a monoclinic prism whose vertical faces are inclined towards each other at an angle of 86° 31′, which are generally aggregated into a crystalline fibrous incrustation. When exposed to the air it loses some of its water and effloresces. The latter form is its mode of condition on the lavas of Vesuvius, and in the salt mines of Hallstadt; while the former is the condition in which it is found at Guipuscoa, in Spain, and Windsor, in Nova Scotia. It is dissolved in many springs and salt lakes. The colour is usually white, the taste is bitter and saline, the hardness 1·5 to 2, and the sp. gr. 1·48.

GLAUBERITE. ($\overline{Na : CaSO_4}$.)

The anhydrous sulphate of soda and lime crystallises in forms nearly isomorphous with those of mirabilite. The primary form is a monoclinic prism with the angle made by the vertical faces with each other equal to 83° 20′, and that made by the same faces with the base equal to 104°15′,

One of its crystals is represented in Fig. 5, Pl. II.; but frequently the forms are much flatter. When exposed to damp air it effloresces, and when immersed in water it is decomposed into sulphate of soda and sulphate of lime, the latter being thrown down as a precipitate. This is mainly owing to the great difference in the degree of solubility of these two salts. The colour is yellowish or greyish, the lustre vitreous, the fracture conchoidal, the hardness 2·5 to 3, and the sp. gr. 2·6 to 2·8. It is generally associated with rock-salt or with saliferous clays in its neighbourhood, but sometimes with the deposits of anhydrite in the Keuper marls. Villarubia and Aranjuez, in Spain; Aussee and Ischl, in Austria; Berchtesgaden, in Bavaria; Tarapaca, in Peru; and Vic, in France, are the principal localities where it is found. The specimens met with at the last-mentioned place are coloured red by the admixture with red clay, and are sometimes called *Polyhalite de Vic.* They are quite distinct from *Polyhalite* properly so called.

Polyhalite.

The name alludes to the number of salts which enter into its composition. It is a hydrated sulphate of lime, magnesia, and potash, crystallising in rhombic prisms of 115°, and generally occurring in fibrous compact masses of a grey, flesh-red, or brick-red colour. It has a resinous or pearly lustre, a slightly bitter astringent taste, a hardness of 2 to 2·5, and a sp. gr. of about 2·7. Its composition is very variable. It is associated with rock-salt at various localities, such as Ischl, Hallstadt, Aussee, in Austria; Berchtesgaden, in Bavaria; Vic, in France; and elsewhere.

Lanarkite. ($PbSO_4$. $PbCO_3$.)

A combination of sulphate and carbonate of lead crystallising in monoclinic prisms in which the vertical sides are inclined towards each other at an angle of 85° 48′. The colour is yellowish-white or slightly greenish, the lustre adamantine or pearly, the hardness 2 to 2·5, and the sp. gr. 6·8 to 7. It readily cleaves into thin laminæ,

which are somewhat flexible; fuses before the blowpipe flame into an opaque white globule; and partially dissolves in nitric acid with separation of sulphate of lead. It is found at Leadhills, in Lanarkshire, in crystals; and massive at a few localities in Brunswick, Siberia, and the Tyrol.

Leadhillite. ($PbSO_4$. 3 $PbCO_3$.)

It differs from lanarkite in containing a larger proportion of carbonate of lead; in crystallising in modifications of a right rhombic prism of 120° 20′, such as the hexagonal table, Fig. 6, Pl. II.; in its smaller sp. gr., which is 6·3; while it agrees in most of the other properties mentioned under lanarkite. It is associated with that mineral at Leadhills and in Siberia, and is also found in Cumberland. *Susannite* is a mineral having the same composition, but crystallising in a different system, viz., the hexagonal.

Caledonite.

This is a combination of the carbonates of copper and lead with sulphate of lead, which crystallises in forms derivable from a right rhombic prism of 95°, such as the one represented in Fig. 7, Pl. II. In hardness, sp. gr., behaviour before the blowpipe and towards nitric acid, it agrees with leadhillite. It is found at Leadhills, in Scotland, associated with linarite; at Roughten Gill, in Cumberland; at Tanne, in the Harz; at Rezbanya, in Hungary; and at Mine la Motte, in Missouri.

Linarite. (*Syn.* Cupreous Anglesite.)

This is a compound of sulphate of lead with hydrated oxide of copper. It crystallises in adamantine-lustred monoclinic crystals derived from a prism with the vertical faces inclined towards each other at an angle of 61°, and towards the base at an angle of 96° 25′. One of these secondary forms is shown in Fig. 8, Pl. II. The colour is deep blue, and is destroyed by a moderate heat; the fracture is conchoidal; the hardness is 2·5 to 3; and the

sp. gr. is about 5·4. It is found at Leadhills, in Lanarkshire, associated with cerusite, and from which it is generally produced by alteration; at Red and Roughten Gills, in Cumberland; near Ems; and possibly at Linares, in Spain.

Brochantite.

The crystals appear to be derivative from a right rhombic prism with an angle of 104° 10′; they are well defined, have an emerald-green colour, a vitreous lustre, an almost imperceptibly conchoidal fracture, a hardness of 3·5 to 4, and a sp. gr. of about 3·8. One of the modified forms is shown in Fig. 10, Pl. II. It is a rare mineral, and is associated with malachite and copper in a copper mine near Ekatherinenburg, in the Ural Mountains; with malachite at Roughten Gill, Cumberland; and with azurite at Rezbanya, in Hungary. A few other localities are known.

Königite and *Krisuvigite* are probably impure varieties.

Alunite. (*Syn.* Alumstone.)

Alunite is much used as a source of alum, whence its name of alumstone. It is a hydrated sulphate of potash and alumina, and occurs in small crystals whose dominating form is a slightly acute rhombohedron of 89° 10′. The colour is greyish or reddish; the lustre vitreous or pearly; the fracture uneven in crystals, but splintery in the massive form; the hardness 3·5 to 4; and the sp. gr. 2·5 to 2·7. It is infusible by itself before the blowpipe, and insoluble in water; but it is soluble in sulphuric acid after it has been powdered. It is generally found in connection with volcanic rocks. Its best-known locality is Tolfa, near Civita Vecchia; while others occur near Mount Dore, in France; Musay, in Hungary; and Elizabethpol, in Georgia.

Websterite. ($Al_2SO_6 + 9\ H_2O$. *Syn.* Aluminite.)

A hydrated sulphate of alumina found in clay at Halle, in Saxony; near Newhaven, in Sussex; near Epernay and

Auteuil, in France; as also in the Laach lava. It is a soft white substance, which generally occurs in reniform and botryoidal masses, or in tabular layers. It has considerable resemblance to ordinary white chalk, but may be at once distinguished from it by the prismatic crystals which may be seen in well-washed powdered websterite. Its hardness is about 1, so that it readily receives impressions from the finger-nail, and its sp. gr. is 1·7. It is insoluble in water, but dissolves in hydrochloric acid without effervescing, and adheres to the tongue. It is almost exclusively confined to tertiary clays, and is generally associated with gypsum, lignite, and iron pyrites.

COQUIMBITE. (Fe_2O_3. 3 SO_3 + 9 H_2O. *Syn.* White Copperas.)

This mineral is found in white (inclining to brown, yellow, green, or blue) crystals belonging to the hexagonal system. They are generally in the form of six-sided prisms with truncated pyramidal summits, which have an indistinct cleavage parallel to the faces of the prism. The lustre is vitreous, the taste astringent, the fracture conchoidal, the hardness 2·25, and the sp. gr. 2. It is soluble in cold water and in hydrochloric acid with separation of a little silica, which is generally present in minute quantities. When heated by the blowpipe the water and acid are given off, and the ferric oxide remains behind. It is found in a felspathic rock near Copiapo, in the province of Coquimbo, Chili, associated with iron pyrites, from which it appears to have been derived by the action of the weather; and near Calama, in Bolivia. Scacchi found it in abundance round fumaroles after the eruption of Vesuvius in 1855. The mineral named *Blakeite* has the same chemical composition as coquimbite, but it crystallises in octahedral forms. *Copiapite* occurs as an incrustation on coquimbite, and appears to be simply a somewhat impure form of that mineral. Some authors, however, consider it to be a distinct species. *Fibroferrite*, *Pittizite*, *Misy*, and *Tecticite* also appear to be species

founded upon more or less altered states of coquimbite. *Voltaite*, a dark green mineral, crystallising in octahedrons, is apparently a combination of the elements of coquimbite and melanterite.

Alunogen. (Al_2O_3. 3 SO_3 + 18 H_2O.)

A hydrated sulphate of alumina, which differs from websterite in containing larger proportions of sulphuric acid and water. It is found in white fibrous or scaly masses, which are soluble in water, and have an astringent taste like alum. The hardness is about 1, and the sp. gr. 1·6 to 1·8. It is found in clays, and, like websterite, appears to result from the action of water and weather on iron pyrites. As will be seen, it closely resembles that mineral, the principal physical distinction being that the one is soluble, while the other is insoluble, in water. Its localities are Arraya, near Cumana; Copiapo, in Chili; Adelaide, New South Wales; Vesuvius; and Smoky Mountain, Jackson co., Carolina.

Alum.

The name for a group of minerals having a composition which may be expressed by the general formula rO. Al_2O_3. 4 SO_3 + 24 H_2O, in which r stands for potassium (K_2), or soda (Na_2), or ammonium (NH_3), or iron (Fe), or manganese (Mn), or magnesium (Mg). They all crystallise in the regular system; they are soluble in water, and generally in octahedrons; their taste is astringent. When heated by the blowpipe they give off their water, and swell up into a white opaque powdery mass. The iron alum, however, becomes red. The *potash alum* is the most common, and is usually found in the form of an efflorescence or an incrustation, with a mealy and sometimes a fibrous structure. It is abundant in clays, argillaceous schists (which, when largely impregnated with alum, are termed aluminous schists or shales), in solfataras, and in the craters of certain volcanoes. Whitby, in Yorkshire; Chudleigh, in Devonshire; Hurlet, near Paisley; Vesuvius; Stromboli; the Egyptian deserts; Cape

Sable, in Maryland, United States, are a few of the many localities that have been recorded. *Soda alum* (*Solfatarite*) has a general resemblance to potash alum, but is rather more soluble in water. It occurs in fibrous crusts lining the solfataras near Naples, and in the province of St. Juan, in South America. *Ammonia alum* occurs in vitreous fibrous masses at Etna, and in the lignite deposits at Tschermig, in Bohemia. *Magnesia alum* (*Pickeringite*) occurs in silky-lustred fibrous masses near Iquique, in Peru, and at the Cape, South Africa. *Manganese alum* (*Apjohnite*) forms masses with a fibrous structure and silky lustre, which have some resemblance to asbestos in appearance. The *iron alum*, or *Halotrichite*, forms yellowish-white silky masses at Hurlet, near Paisley; Morsfield and Bodenmais, in Rhenish Bavaria; and at Oroomiah, in Persia. It differs somewhat from the other alums in turning red when heated.

NITRATINE. ($NaNO_3$. *Syn.* Cubic Nitre; Nitrate of Soda.)

Its crystals are obtuse rhombohedrons of 106° 30′, which at first sight might be mistaken for cubes, whence its name of cubic nitre: it presents a tolerably easy cleavage parallel to all its faces. It has a white colour, a vitreous lustre, an imperfectly conchoidal fracture, a hardness of 1·5, and a sp. gr. of 2·2 (24,591). It is slightly deliquescent, readily dissolves in water, and has a bitter saline taste. It melts at about 590° F., is decomposed at a red heat, and deflagrates when heated along with organic substances or charcoal. In this last respect it resembles saltpetre, but differs from it by its slight hygroscopicity, and by the greater slowness of the deflagration. It forms beds several feet thick in the district of Tarapaca, Chili, where it is associated with gypsum, and also in Bolivia and Peru. It is generally mixed more or less with sand and common salt.

SALTPETRE. (KNO_3. *Syn.* Saltpetre; Nitre; Prismatic Saltpetre.)

It crystallises in two distinct systems, either as hexagonal prisms or rectangular tables derivable from a right rhombic prism of 119° 10′, or in rhombohedrons of 106° 36′. The former is that to which the native crystals usually belong, which somewhat resemble arragonite; the latter is the form obtained artificially by slowly cooling its solution, and is isomorphous with calcspar. Saltpetre is white, inodorous, not deliquescent, fuses less readily than nitratine, is decomposed at a red heat with evolution first of oxygen, and then of oxygen and nitrogen, and deflagrates more readily than nitratine with combustible bodies. Deflagration is a phenomenon of an exceedingly complex character, but adopting very general terms, it may be said to be the sudden evolution of a quantity of oxygen, which oxygen, being in a nascent state, gives rise to various oxidised products, which are mostly in a gaseous state. This sudden expansion is the chief source of the explosive power of gunpowder, while the heat and light result from the combination of the oxygen with sulphur and carbon. Saltpetre has a cooling, saline taste, a vitreous lustre, a hardness of 2, and a sp. gr. of 1·9. It is widely distributed, but seldom occurs in thick beds like nitratine. It is constantly forming in the neighbourhood of decomposing organic matter, especially in stables and certain caves; such as those in Ceylon, America, and elsewhere, which are inhabited by large numbers of bats. It is distributed through many limestones and soils.

NITROCALCITE. ($CaNO_3$. $2H_2O$. *Syn.* Saltpetre Rot.)

This is a deliquescent, readily soluble salt, which occurs in white or grey efflorescent silky masses, under circumstances somewhat similar to those which attend the formation of saltpetre, viz., on the walls of badly-drained inhabited places, such as limestone caverns, stables, &c. It has a warm, bitter taste, and a sp. gr. of 2·47 when anhydrous. When heated the water is driven off, and

the anhydrous salt is decomposed at a heat higher than that required for nitratine and saltpetre, with evolution of oxygen and anhydrous nitric acid. It deflagrates with combustible powder at a red heat, but far less powerfully than the preceding salts.

NITROMAGNESITE ($MgNO_3$. 3 H_2O) has considerable resemblance to nitrocalcite, and is frequently associated with it.

BORACITE. (3 MgO. 4 B_2O_3 + MgCl. *Syn.* Borate of Magnesia.)

It crystallises in hemihedrally-modified cubes, rhomboidal dodecahedrons, and other forms belonging to the cubic system. The colour is white, inclining to green, yellow, or grey; the lustre is vitreous, the fracture conchoidal, the hardness 6·5, and the sp. gr. 2·95. It is insoluble in water, but soluble in dilute acids; fuses before the blowpipe into a globule covered externally by acicular crystals. When heated the crystals of boracite exhibit the phenomena of pyroelectricity. It occurs in the saccharoidal gypsum near Luneburg, in Brunswick, associated with quartz; at Kalkberg, associated with rock-salt; and Segeberg, associated with karstenite. Fig. 64 represents a boracite crystal.

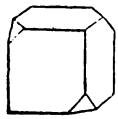

Fig. 64.

RHODIZITE.

A mineral resembling boracite in constitution, crystalline form, and general physical properties, but containing calcium in the place of magnesium. It occurs as minute white tetrahedral crystals on the quartz and rubellite in the clay-filled fissures of the granites near Sarapulsk, in the Ural Mountains. Their hardness is 8, and their sp. gr. 3·4. They are eminently pyroelectric.

BORAX. (*Syn.* Biborate of Soda; Tincal.)

A number of salts are included under this term. Ordinary borate of soda is $Na_2O.B_2O_3$, or $NaBO_2$; the biborate is $Na_2O.2B_2O_3$, or $Na_2B_4O_7$; and borax is the

first in various states of hydration. There are two principal kinds, viz., that which crystallises as octahedrons, having a conchoidal fracture, a sp. gr. of 1·8, and a composition corresponding to $NaBO_2 + 2\frac{1}{2} H_2O$; and that which crystallises in oblique prisms isomorphous with augite, having a sp. gr. of 1·74, and a composition corresponding to $NaBO_2 + 5 H_2O$. The last-mentioned is the ordinary native borax, which is a white or greenish-grey, sweetish-tasting, soft substance, readily soluble in water, and easily fused by the blowpipe. It is found abundantly in certain salt lakes of Asia, round the borders of which it accumulates during hot and dry weather as a crystalline deposit; it is also found, though in smaller quantities, in mineral springs at Chambly, St. Ours, and other places in Canada, and in Peru.

LARDERELLITE. ($NH_4 BO_2 + H_2O$.)

A borate of ammonia found in the form of flat rectangular yellowish-white transparent crystals in the lagoons of Tuscany. It is readily soluble in water. A borate of iron ($FeBO_2 + 1\frac{1}{2} H_2O$) has also been found in the same locality. It forms ochreous-yellow incrustations, and is called *Lagonite.*

HYDROBORACITE.

It has considerable resemblance to fibrous gypsum, and appears to be a hydrated borate of lime and magnesia. It is a white translucent substance, generally spotted with red ferruginous clay. It readily melts before the blowpipe into a clear glass, is slightly soluble in water, and readily soluble in nitric acid.

BOROCALCITE. ($CaBO_2 + aq.$ *Syn.* Hydroborocalcite; Hayesite.)

A borate of lime forming a white crystalline efflorescence on the plain of Iquique, in Ecuador, South America. A similar mineral has also been found in one of the lagoons of Tuscany. *Boronatrocalcite* is somewhat similar, but contains some sodium, and more water.

Struvite

A hydrated phosphate of ammonia and magnesia, crystallising in six-sided prisms, and having, when pure, a yellow colour. It is soluble in water and acids, and tasteless; its lustre is vitreous, its hardness is 2, and its sp. gr. 1·7. Before the blowpipe it evolves water and ammonia, and fuses into an opaque enamel. It has been found in the guano of Saldanha Bay, Africa, and in a layer of soil largely impregnated with animal matter beneath the church of St. Nicholas, Hamburg.

Apatite. (*Syn.* Phosphorite; Agustite; Moroxite.)

Most specimens of this mineral are apparently fluo-phosphates of lime, but in some rare cases the fluorine is said to be absent; so that probably it is not an essential ingredient. The crystals are six-sided prisms with modified edges, as shown in Fig. 65. Their lustre is vitreous, their hardness 5, and their sp. gr. 3·2. Some specimens are colourless and transparent, while others are various shades of green, yellow, blue, and red, while the amorphous are quite devoid of lustre. Apatite is with difficulty fused by the blowpipe, and is soluble in both nitric and hydrochloric acids. *Asparagus stone* is a greenish-yellow variety from Zillerthal in Tyrol, and Villa Rica in Spain; *moroxite* is a green variety from Arendal, in Norway; and *phosphorite* is the earthy variety whose powder becomes more or less phosphorescent when heated.

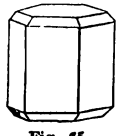

Fig. 65.

Apatite is found in rocks of almost every age and degree of consolidation. Thus phosphate of lime nodules occur in the limestones of the Laurentian system, in the clays of the coal measures, in the chalk and greensand of France and England, and in several clays of the tertiary formation. It occurs in a crystalline state in rocks of the granitic family, and is associated with the tin ores of Cornwall and Saxony. The schists of Norway, Switzerland, and elsewhere contain it, as also the trachytes, lavas, and allied volcanic rocks of Germany, Spain, Italy, and other countries.

PHARMACOSIDERITE. (*Syn.* Cube Ore.)

A hydrated arsenate of iron occurring in forms belonging to the regular system, and very similar to those of boracite. The colour is generally an olive-green, inclining to blackish-brown in the partially-decomposed specimens; the lustre is indistinctly adamantine, the hardness 2·5, and the sp. gr. 2·9 to 3. When heated it gives off water and turns red. At a higher temperature it evolves arsenical vapours, and fuses into a grey shiny slag. It is soluble in hydrochloric and nitric acids. It was first found in some of the Cornish mines lining cavities in quartz; amongst others, Huel Jane, Huel Gorland, and Carharrack mine. It also occurs at Burdle Gill, Cumberland, associated with quartz; at Graul, near Schwarzenberg, in Saxony; at Puy les Vignes and St. Léonard, in France; and in Australia. This mineral is probably a ferrosi-ferric arsenate corresponding to the formula $Fe_3O_4 . As_2O_5 + 6\,H_2O$.

SCORODITE. ($Fe_2O_3 . As_2O_5 + 4\,H_2O$, or $Fe\,AsO_4 + 2\,H_2O$.)

This differs from the foregoing species in being a ferric arsenate, and in crystallising in forms derivable from a right rhombic prism whose vertical faces are inclined towards one another at an angle of 98°. The colour is a bluish green, somewhat like that of sulphate of iron, but it becomes brownish in decomposed specimens. The lustre is vitreous, the hardness 3·5, and the sp. gr. about 3·2. When calcined it first gives off water, then arsenical fumes, and ultimately it fuses into a greyish magnetic globule with a metallic lustre. It is readily soluble in hydrochloric acid. It is generally found in the same localities as pharmacosiderite. *Pitticite* is a mineral whose composition has not been well determined, but it appears to be a mixture of the hydrated arsenate and sulphate of iron.

VIVIANITE. (*Syn.* Anglarite; Blue Iron Earth.)

This name is applied to several phosphates of iron. It should, perhaps, be restricted to the tri-ferrous phosphate

answering to the formula $3\,FeO.\,P_2O_5 + 8\,H_2O$, or $Fe_3^2\,PO_4 + 4\,H_2O$. The minerals assigned to it are, however, composed of hydrated ferric and ferrous phosphates mingled together in numerous proportions. It crystallises in monoclinic crystals, which are derivable from an oblique prism almost identical with the primary form of gypsum. Like that mineral, it possesses a perfect cleavage parallel to one of its lateral faces, and yields laminæ which are slightly flexible. The faces thus produced have a metallic pearly lustre, while the others are vitreous. The colour is a pale green or an indigo-blue, which is darkest in the most weathered specimens. Unaltered specimens are almost colourless, as also are the nuclei of many earthy varieties. Artificial ferric phosphate has no colour, but is turned blue by oxidation; so that it may be inferred that the blue of the natural phosphate is also due to oxidation. The hardness is about 2, and the sp. gr. 2·66. It is insoluble in pure water, slightly soluble in carbonated water, and readily in hydrochloric or nitric acids. Fine crystals of vivianite occur at Huel Kind and other localities in Cornwall; at Odin mine, in Derbyshire; at Bodenmais, in Bohemia, in gneiss; in basalt at Bonèche, in France; in fossil shells at Kertsch, in the Crimea; at Mullica Hill, in New Jersey, United States (var. *Mullicite*), and at Anglar, in France (var. *Anglarite*). The earthy varieties frequently occur as reniform, globular, or fibrous masses, in muds and clays containing organic matter and iron oxides, and occasionally in bones and in the stomachs of animals which have swallowed bits of iron.

Erythrine. (*Syn.* Cobalt Bloom.)

A hydrated arsenate of cobalt corresponding to, and isomorphous with, the foregoing phosphate. Its primary form is a monoclinic prism with a very perfect cleavage parallel to one of its lateral faces, and readily yielding thin, slightly flexible laminæ. The lustre is pearly on the cleavage faces, and vitreous on the others. The

colour is a carmine or rosy red; the hardness varies from 1·5 to 2·5; and the sp. gr. is 2·99. Its composition may be represented by the formula $3\,Co\,O\,As_2O_5 + 8\,H_2O$, or $Co_3^2\,As\,O_4 + 4\,H_2O$. When heated, a little of the arsenical acid is evolved in fumes, and the remainder fuses into a blue glass. It is readily soluble in hydrochloric acid. Its principal localities are Carn Brea, Dolcoath, and elsewhere in Cornwall; Broomfield Consols mine, in Somersetshire; Schneeberg, in Saxony; and Arendal, in Norway.

Nickel Bloom ($Ni_3^2\,As\,O_4 + 4\,H_2O$) is isomorphous with erythrine, and occurs as an apple-green incrustation in a mine at Annaberg, whence the name *Annabergite*, which is sometimes given to it. Its sp. gr. is about 3·1.

Dufrenite. (*Syn.* Green Iron Ore; Kraurite.)

A hydrated phosphate of iron whose composition answers to the formula $Fe_2PO_{11} + 2\frac{1}{2}\,H_2O$, or $2\,Fe_2O_3\,P_2O_5 + 5\,H_2O$. Its primary form is a trimetric prism, with an angle of 123°. The colour is leek-green in fresh specimens, but brownish or yellow in the more altered ones. Its lustre is weak, its hardness 4, and its sp. gr. 3·4. It is easily fused. It occurs in botryoidal masses with a fibrous structure, and in crystals associated with magnesium phosphates at Limoges, with limonite at Siegen, and at Allen Town, in New Jersey, United States. *Melanchlor* may be a variety of dufrenite.

Hureaulite.

It is a hydrated phosphate of iron and manganese, occurring in rose-red or reddish-yellow translucent crystals in veins traversing pegmatite at Hureaux, near Limoges. These crystals belong to the monoclinic system, and their primary form is a prism of 61°. They are associated with triphylline and heterosite. Their hardness is 3·5; their sp. gr. 3·2. They are soluble in acids, and readily melt before the blowpipe.

Heterosite.

This also is a hydrated phosphate of manganese and iron, containing more ferrous oxide and less water and manganous oxide than the hureaulite. It has a greenish or bluish-grey colour when fresh, but a fine violet tint when altered. Its sp. gr. is 3·5, and it occurs along with hureaulite.

Triphylline.

A complicated isomorphous mixture of the hydrated phosphates of iron, manganese, and lithium. The minerals assigned to it vary considerably in the composition, and hence scarcely any two authorities agree in the formula they give it. The crystals are rare, and somewhat resemble the topaz. The colour is greenish-grey or bluish, passing into brown and black by decomposition. The lustre is resinous; the hardness 5; and the sp. gr. 3·6. It dissolves readily in acids, and yields a magnetic black slag when fused by the blowpipe. It is found at Bodenmais, in Bavaria, associated with the common beryl. *Tetraphylline*, *Alluaudite*, *Pseudotriplite*, and the black crystals found at Norwich, in Massachusetts, are probably altered varieties of triphylline.

Triplite.

An anhydrous phosphate of manganese and iron found in the pegmatite of Alluaud, near Limoges, associated with the foregoing phosphates. It forms crystalline masses, having a blackish or dark brown colour, a resinous lustre, a flat conchoidal fracture, a hardness of 5·5, and a sp. gr. of 3·5. It is soluble in hydrochloric acid, and readily fuses into a magnetic black globule.

Zwiesilite. (*Syn.* Iron Apatite.)

This mineral very nearly resembles triphylline, but differs from it in containing a little fluorine. Its sp. gr. is 3·9. It forms lumps in the granite at Zwiesel, near Bodenmais, Bavaria.

MONAZITE (*Syn.* Edwardsite; Mengite; Eremite.)

A phosphate of cerium, lanthanum, and thorinum, occurring in small flat crystals of a brownish-red or yellowish-brown colour, a resinous lustre, a hardness of 5 to 5·5, and a sp. gr. 4·9. It is soluble in hydrochloric acid, but infusible by the blowpipe, the heat of which simply turns it greyish. It is found in granite at Slatoust, in the Ural Mountains; at Norwich, in Connecticut; at Rio Chico, in New Granada; near Crowder's Mountain, North Carolina; and at Halle, in Norway.

WAGNERITE.

A fluo-phosphate of magnesia ($3\,MgO.\,P_2O_5 + MgF_2$ or $Mg_2F\,PO_4$) crystallising in monoclinic crystals of a yellowish colour and a vitreous lustre. The hardness is 5·5; the fracture splintery and uneven; and the sp. gr. 3·16. It is fused, on the edges only, by the blowpipe into a greenish-grey glass, and when put into hot sulphuric acid it evolves vaporous hydrofluoric acid. It is a rare mineral, the only locality being the quartz veins traversing the clay slate of Hollengraben, near Werfen, in Salzburg.

AMBLYGONITE.

This is a rare mineral, whose composition has not been definitively determined. It is considered to be phosphate of alumina and lithia, which generally contains more or less fluoride of aluminium and lithium. It is found in minute rhombic prismatic prisms of a greenish colour, and with a vitreous lustre. It is fusible by the blowpipe into a glass which is opaque white when cold. It is found in the granite of Chursdorf, near Penig, in Saxony, associated with tourmaline and topaz; at Arendal, in Norway; and at Hebron, in Maine.

Herderite is another rare mineral about which little is known. It appears to be nearly allied to amblygonite, and to be a phosphate of alumina and lime, mixed with a little fluoride of lime. It is found in the tin mines of

Ehrenfriedersdorf, in Saxony, associated with fluorspar and apatite.

LAZULITE. (*Syn.* Klaprothine; Voraulite; Azurite; Blue Spar.)

A hydrated phosphate of alumina and magnesia, generally containing a little phosphate of iron. It crystallises in monoclinic prisms of 91° 30′, which are generally modified on their basal edges by a set of faces which give the terminations somewhat the appearance of rhombic octahedrons. It is usually met with in granular masses. Its colour is blue, but of different shades in different directions; thus, when looked through in the direction of one axis it is deep blue, but when looked through in another direction it is greenish blue. Some varieties have a grey or brown colour. Its lustre is vitreous; its fracture uneven; its hardness between 5 and 6; and its sp. gr. 3·1. At a moderate heat water is given off, and the colour is destroyed; at a higher heat it swells up and falls into a powder, but does not fuse. After it has been ignited it is completely soluble in acids. It is found in the quartz veins traversing the mica schists near Werfen, in Salzburg; near Vorau, in Styria; at Zermatt; Tijuco, in Minas Geraes province, Brazil; at Crowder's Mountain, in Lincoln co., North Carolina; and in Georgia.

CALAITE. (*Syn.* Turquois; Agaphite; Johnite.)

A hydrated phosphate of alumina, which at present is only known in an amorphous state. It has a peculiar bluish-green colour, a slightly conchoidal fracture, a waxy lustre, a hardness of 6, and a sp. gr. of about 2·6. When heated the water is driven off, and the mineral turns black; when acted on by the blowpipe it turns brown without swelling up, and colours the flame green. It is soluble in acids without effervescence, by which character it may be distinguished from another mineral, known as occidental or bone turquois, which is bone coloured by certain metallic oxides. Calaite is found near Nichabour, or Nishapúr, in Persia; at Jordansmühle, in Silesia; and

at Oelsnitz, in Saxony. The formula generally given to it is $2\ Al_2O_3.\ P_2O_5 + 5\ H_2O$.

Peganite differs little from calaite, so far as chemical composition is concerned, being represented by $2\ Al_2O_3.\ P_2O_5 + 6\ H_2O$. It is found at Striegis, in Saxony, in crystalline crusts formed of acicular rhombic prisms of about 127°. Their colour is greenish; their hardness about 4; and their sp. gr. 2·49 to 2·54.

Fischerite is a mineral very similar to that last described. It occurs in greenish masses, composed of rhombic prisms of 118° 32′, and having a sp. gr. of 2·4. It is found in clay slate at Nischne Tagilsk. Its formula is $2\ Al_2O.\ P_2O_5 + 8\ H_2O$.

Wavellite. (*Syn.* Devonite; Lasionite.)

It is a hydrated phosphate of alumina, generally represented by the formula $3\ Al_2O_3.\ 2\ P_2O_5 + 12\ H_2O$. It occurs in mammillated or globular concretions having a fibrous structure, which are composed of an aggregation of rhombic prisms of 126° 25′. Their lustre is vitreous, inclining to pearly; their colour is white or greyish in the crystals, and greenish-blue, yellow, or dark brown in the mass; their hardness is 3·5; and their sp. gr. 2·3. When moderately heated the water is given off, while at a higher temperature it swells up, turns white, and at the same time the flame is tinged greenish. It is soluble in hot acids. Its localities are in veins traversing clay slate at Barnstaple, in Devonshire; St. Austell, in Cornwall; at Clonmel and Cork, in Ireland; in Scotland; at Zbirow, in Bohemia; and other localities in Bavaria, Greenland, Mexico, United States, and Brazil.

Variscite is probably an amorphous variety.

Haidingerite.

A hydrated arsenate of lime, occurring in minute trimetric prisms aggregated into crusts and botryoidal masses. Its lustre is vitreous; its hardness 1·5 to 2·5; and its sp. gr. 2·8. It is exceedingly rare; the few specimens in cabinets are supposed to have come from

Joachimsthal, in Bohemia. Crystals similar to haidingerite have been formed artificially.

Pharmacolite.

This, like the last, is a hydrated arsenate of lime, but it differs in containing a larger proportion of water. It generally occurs in acicular prisms, or small fibrous mammillated masses. The crystals are monoclinic; their lustre is vitreous; their fracture uneven; their hardness 2·5; and their sp. gr. 2·7. They are generally white, but are sometimes tinged with red. When heated on charcoal, arsenical fumes and water are given off, and at a higher temperature it fuses into a white enamel. It is associated with gypsum and barytine at Wittichen, in Suabia, and probably with haidingerite at Joachimsthal, in Bohemia. It is also found at Riechelsdorf, in Hesse; Andreasberg, in the Harz; and at St. Marie aux Mines, in the Vosges.

Picropharmacolite is a variety containing a small proportion of magnesia.

Lunnite. (*Syn.* Phosphochalcite.)

A mineral of an emerald-green colour found in fibrous or radiated masses, which are composed of monoclinic prisms. The hardness is 5, and the sp. gr. is 4·3. Lunnite is soluble in ammonia and nitric acid; when calcined it gives off water, and yields a globule of copper when fused with soda or charcoal. It is a hydrated phosphate of copper. Its principal localities are Cornwall; Nischne Tagilsk, in the Urals; Hirschberg, in the Voigtland; Ehl, on the Rhine; and Virneberg, in Rhenish Prussia. Its formula is $6\,CuO.P_2O_5 + 3\,H_2O$.

Libethenite.

A hydrated phosphate of copper ($4\,CuO.P_2O_5 + H_2O$), of a green colour, a resinous lustre, a hardness of 4, and a sp. gr. of 3·6. It is found in mica schist at Libethen, in Hungary; Nischne Tagilsk, in the Ural Mountains;

at Gunnis Lake, near Callington, in Cornwall; in Chili, Bolivia, and Africa.

Pseudolibethenite is a similar mineral, but contains two atomic proportions of water. The crystals of libethenite are right rhombic prisms of 92° 20′, and are isomorphous with those of olivenite.

Tagilite ($4\ CuO.\ P_2O_5 + 3\ H_2O$), *Dihydrite* ($5\ CuO.\ P_2O_5 + 2\ H_2O$), and *Ehlite* ($5\ CuO.\ P_2O_5 + 3\ H_2O$), are minerals closely allied to libethenite, and distinguished from it by very slight differences in their physical properties.

OLIVENITE. (*Syn.* Prismatic Arsenate of Copper; Pharmochalcite.)

An arsenate of copper in which a portion of the arsenic acid is frequently replaced by phosphoric acid. It occurs in spherical lumps with a fibrous structure, due to its being composed of acicular prisms; the prisms are right rhombic with an angle of 92° 30′. Fig. 26, Pl. II., represents a crystal of libethenite, and Fig. 27, Pl. II., a crystal of olivenite. The lustre is vitreous, the colour olive-green, the fracture conchoidal or uneven, the hardness 3, and the sp. gr. 4·1 to 4·4. Its chemical formula is $4\ CuO.\ \overbrace{As : P_2}\ O_5 + H_2O$. Its principal localities are Redruth, in Cornwall; Alston Moor, in Cumberland; Zinnwald, in Bohemia; Nischne Tagilsk, in the Urals; Camsdorf, in Thuringia; and elsewhere.

ERINITE. (*Syn.* Chalcophyllite.)

A hydrated arsenate of copper corresponding to dihydrite amongst the phosphates, so far as chemical composition is concerned ($5\ CuO.\ As_2O_5 + 2\ H_2O$). It is an emerald-green substance, crystallising in transparent hexagonal plates, which have a remarkably easy cleavage parallel to their large faces. Their hardness is 4·5 to 5, and sp. gr. 4·04.

Clinoclase (*Syn.* Aphanese; Abichite) is, chemically, very similar to erinite, its formula being $5\ CuO.\ As_2O_5 + 5\ H_2O$. It has a bluish-green colour, a hardness

of 3, and a sp. gr. of 4·4. It is found along with other arsenates of copper in Cornwall, and near Saida, in the Erzgebirge.

Tyrolite (*Syn.* Leirochroite; Kupferschaum) has the same formula as the last, with the addition of 5 H_2O. It forms reniform masses, with a radiated structure, having a pale green colour, a pearly lustre, a hardness of 1·5 to 2, and a sp. gr. of 3·1. It generally contains a little carbonate of lime, so that when immersed in an acid it dissolves with effervescence. It is found at Falkenstein, in the Tyrol; at Posing, in Hungary; in Siberia, Italy, and Spain.

Euchroite is a hydrated arsenate of copper, having the formula 4 CuO. $As_2O_5 + 7\ H_2O$. It crystallises in right rhombic prisms of 117° 20′. Its hardness is 4, its sp. gr. 3·4, and the only recorded locality is Libethen, in Hungary.

Liroconite. Its formula is 4 CuO. $As_2O_5 + 10\ H_2O$. It crystallises in trimetric crystals, having a blue colour, a hardness of 2 to 2·5, a sp. gr. of 2·9, and a vitreous lustre. When heated it first turns green, then brown, and ultimately melts into a red globule. It is found at Huel Gorland and Huel Unity, in Cornwall; at Herrengrund, in Hungary; and at Ullersreuth, in the Voigtland.

Pyromorphite. (*Syn.* Green Lead Ore.)

It crystallises in hexagonal prisms (Fig. 24, Pl. II.), having a green, yellow, or brown colour. The lustre is resinous, the hardness 3·5 to 4, and the sp. gr. 6·9 to 7. It is readily fusible by the blowpipe, and soluble in acids. It is a phosphate of lead combined with a chloride of lead, and is isomorphous with mimetesite and apatite. By the mingling of these three species a number of minerals are formed. Pyromorphite is found in association with galena and cerusite, at Huelgoët, in France; Hoffsgrund, in Brisgau; Zschopau, in Saxony; Zellerfield, in the Harz; and in many other localities.

MIMETESITE. (*Syn.* Mimetite; Hedyphane; Kampylite.)

A yellowish-green substance isomorphous with pyromorphite, and including a number of minerals which are either pure arsenate of lead combined with chloride of lead, or a mixture of this with one or other of the varieties of apatite or pyromorphite. It crystallises in hexagonal prisms, having a hardness of 4, and a sp. gr. of 7·2 in the purer specimens. The colour is pale yellow, and the lustre is resinous. In kampylite the colour is orange-yellow, owing to its containing a little chromate of lead; while in hedyphane it is whitish, in consequence of the presence of phosphate of lime. It is fusible by the blowpipe, and soluble in nitric acid. Mimetesite occurs in well-defined crystals at Badenweiler, in Baden; at La Blanca, Zacatecas, in Mexico; at Phœnixville, in Pennsylvania; at Preobrajansk mine, in Siberia; at numerous localities in Cornwall, Cumberland, and Yorkshire; in Chili, and in Sweden. Hedyphane is found at Langbanshytta, in Sweden; and kampylite at Caldbeck Fell, in Cumberland. The last-mentioned variety occurs in prisms with curved faces, which have some resemblance to a barrel in form.

XENOTIME. ($3\,YO.\,P_2O_5$.)

A phosphate of yttria crystallising in dimetric octahedrons, having a yellowish-brown or flesh-red colour. Their hardness is 4·5; their sp. gr. 4·5; their lustre resinous; and their fracture uneven and splintery. It is infusible by the blowpipe, and insoluble in acids. It is found in granite, associated with orthite and polycrase at Hitteroë, in Norway; and Ytterby, in Sweden. It has also been met with in the gold washings of Clarkeville, in Georgia.

Castelnaudite appears to be an impure variety. It occurs in grains and small crystals in the diamond-containing sand of Bahia.

CRYPTOLITE.

It is a phosphate of cerium from the apatite of Arendal,

in Norway. It crystallises in wine-yellow hexagonal prisms, having a sp. gr. of 4·6. Its formula, 3 CeO. P_2O_5, is analogous to that of xenotime.

Phosphocerite is apparently a variety containing a small proportion of the phosphates of lanthanum and didymium.

CHALCOLITE. (*Syn.* Copper Uranite; Torberite.)

A mineral having an emerald-green colour, inclining to yellowish-green, and crystallising in dimetric octahedrons or prisms. Chemically it is a hydrated phosphate of copper and uranium. The hardness is 2·5; the sp. gr. 3·6. It fuses before the blowpipe into a dark mass, and imparts a bluish-green colour to the flame. It is soluble in nitric acid, yielding a yellowish-green solution. It is found in the tin and other metallic lodes traversing the granitic and micaceous rocks. The gangue is an opaque quartz, and the associated minerals are fluorspar and felspar. It is found at Gunnis Lake, and near Redruth, in Cornwall; at Eibenstock and elsewhere in Saxony; at Joachimsthal, in Bohemia; and in Belgium.

URANITE. (*Syn.* Lime Uranite; Uranium Mica.)

It has a citron-yellow colour, and crystallises (though rarely) in minute well-defined crystals, whose primary form is a right rhombic prism of 90° 43′. Its usual mode of occurrence is in laminated clusters. The sp. gr. is 3·2, the hardness is 1·2, and the lustre is pearly on some faces, but adamantine on others. When heated the water is partially driven off, and the mineral becomes opaque. It fuses into a dark-coloured globule, and is soluble in nitric acid, yielding a yellow solution. The latest researches on this mineral appear to indicate that its formula is $\overbrace{Ca : U_2}\ O_3\ P_2O_5 + 12\ H_2O$. It is found in the granitic rocks near Limoges and Autun, in France; at Eibenstock, in Saxony; at Wolf Island, Lake Onega, in Russia; at Chesterfield, Massachusetts; at Ackworth, New Hampshire; and at Branchville in Conn.

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Hydrocyanite.

This is the anhydrous sulphate of copper, crystallising like other sulphates in the trimetric system, the principal angle of the primary rhombic prism being 121° 4′. The colour is pale green, brownish or yellowish, as also sky blue. It is completely soluble in water and readily effloresces in contact with the air. When preserved in the matrix, and not touched, the crystals will remain unaltered for several days, but if they are removed or are touched they change colour almost immediately. The crystals first change by assuming a blue colour owing to the assumption of water, then slowly split up into a number of minute granules or crystals. Efflorescence is usually the consequence of the loss of water, but in this case it is accompanied by absorption of water, and thus becomes converted into ordinary blue vitriol or cyanosite. The name alludes to its property of becoming blue when combined with water. It was found by Scacchi at Vesuvius amongst the products formed by sublimation during the eruption of October, 1868.

Kieserite.

The hydrated sulphate of magnesia with one atomic proportion of water crystallising in the trimetric system. It usually occurs in beds several inches thick. The colour varies from white to yellow; the hardness is 2·5; and the sp. gr. 2·5. It has about the same degree of solubility in water as gypsum. Its association with carnallite and rock salt at Stassfurt is due to the evaporation of sea-water from which these minerals are deposited in definite accordance to the degree of concentration. When the ordinary sulphate of magnesia is exposed at a red heat to a current of steam it is decomposed, but kieserite differs from it inasmuch as all the sulphuric acid is carried off under these circumstances without being decomposed.

Ilesite.

It is a hydrated sulphate of manganese with four atomic proportions of water, met with in loosely adherent masses of prisms, which are white, friable, and easily soluble in water. They have an astringent bitter taste. They form veins 6 to 8 inches wide in Hall Valley, Park co., Colorado.

Mallardite.

This is the hydrated sulphate of manganese with seven atoms of water, analogous to epsomite and allied sulphates. It probably belongs to the monoclinic system. It dissolves with great ease in water, and is rapidly changed when exposed to the weather, effervescing and crumbling into a powder. Carnot found that the salt which crystallised out from a solution of sulphate of manganese at 60° F. consisted of triclinic crystals containing five atomic proportions of water, while at about 40° the seven atom salt appeared in monoclinic crystals. Mallardite occurs in a kind of clay in the Lucky Boy silver mine, near the Salt Lake of Utah.

Nitrobarite.

Colourless crystals of nitrate of barium have been found in Chili, and named nitrobarite, which occurs in octahedrons built up by the twining of positive and negative tetrahedrons.

Fillowite.

It is a phosphate of manganese and iron which seems to be essentially the same as triplite. The crystals appear to be rhombohedral but are really monoclinic. It occurs with other manganesian phosphates in a vein of granite at Branchville, Connecticut.

Eosphorite.

A hydrated phosphate of manganese and iron, the crystals of which belong to the trimetric system,

forming prisms with vertical striæ; but it usually occurs in compact masses. The hardness is 5; the sp. gr. 3·1; the lustre vitreous to subresinous and greasy; the colour rose-pink in the crystals, whence its name, and light shades of grey, yellow, or blue in the compact form. In the closed tube it decrepitates when strongly heated, becomes white, gives off neutral water in abundance, and the residue turns first black, then grey, and finally linen brown, acquires a metallic lustre and magnetic properties. It is fusible by the blowpipe and soluble in acids. It occurs in pegmatite at Branchville, Connecticut, along with other phosphates of manganese.

Childrenite is a similar compound in which the ferrous oxide predominates over the manganese.

Durangite.

An arsenate of alumina and soda which crystallises in monoclinic crystals of a vitreous lustre and of a bright orange-red colour. Hardness 5; sp. gr. 3·95. It easily fuses into a yellow glass. On charcoal it yields a white volatile sublimate with a strong arsenical odour when exposed to the reducing flame. Sulphuric acid decomposes it with evolution of hydrofluoric acid. It is found near Durango, Mexico.

Brushite.

A hydrated phosphate of lime crystallising in monoclinic crystals, which are colourless or pale yellow, pearly and vitreous in lustre. Hardness 2 to 2·5; and sp. gr. 2·2. It fuses easily in the blowpipe flame, intumescing and colouring the flame green. It dissolves readily in dilute nitric and hydrochloric acids. It occurs in the guano on the islands of Aves and Sombrero.

Metabrushite, which is also found on Sombrero, has a similar composition, the chief difference being that it has a smaller proportionate quantity of water.

Uranocircite.

A. H. Church has examined a specimen from Falkenstein, in Voigtland, and finds it to be a baryta-uranite having a composition answering to the formula

$$Ba\,O,\ 2\,UO_3\,P_2\,O_5 + 8\,H_2\,O.$$

It is analogous to chalcolite and uranite, but more nearly resembles the latter, readily parting with most of its water of crystallization.

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